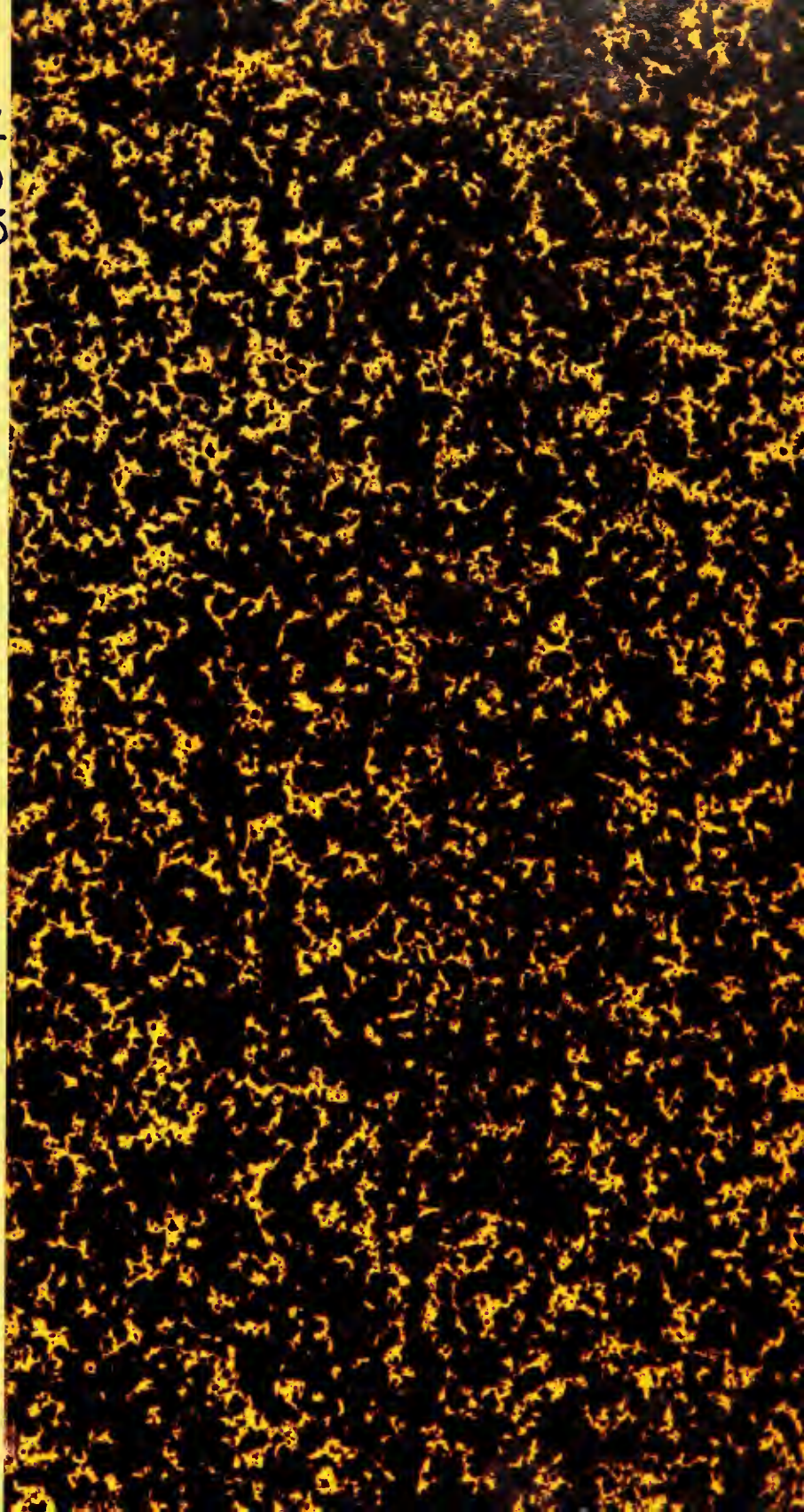

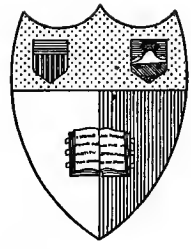

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

EXPLANATION OF SHEET 113.

THE GEOLOGY OF

THE COUNTRY AROUND

OLLERTON:

BY

G. W. LAMPLUGH, F.R.S., J. B. HILL, R.N.,
W. GIBSON, D.Sc., R. L. SHERLOCK, D.Sc.,
AND B. SMITH, M.A.

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PREFACE.

THE original geological survey of the area was made on the Old Series one-inch maps. The major portion, on Sheet 82 S.E., was surveyed by W. T. Aveline and T. R. Polwhele; a small part on the south, on Sheet 71 N.E., by T. R. Polwhele; and portions on the east, on Sheets 70 and 83, by W. H. Dalton.

The re-survey on the 6-inch scale, on which the new map is based, was done in the years 1907–9, by Mr. J. B. Hill, Dr. R. L. Sherlock, Mr. B. Smith, and Mr. G. W. Lamplugh under the superintendence of the last-named officer, who has also acted as editor to the present memoir. The areas for which the surveyors are severally responsible are indicated in the list of 6-inch maps given on p. iv.

The ground described in this memoir is occupied by Triassic rocks, with small tracts of Permian and of the overlying Lias, but the exploiting of the underground palæozoic rocks is in progress in the western part and is being extended eastwards, with the result of proving that Coal Measures underlie the whole area. These Carboniferous rocks, which are continuous with those of the visible coal-field adjoining this area on the west (Sheet 112), are described in Chapter II.

In the Keuper area the thin belts of sandstone or 'skerry' in the red marl have been mapped in detail, and the structure of the country is therefore more clearly brought out than heretofore.

The district is at present mainly agricultural, and except for the deep-seated Coal the only mineral products of much economic consequence are the Moulding Sands of the Lower Mottled Sandstone and the Gypsum of the Keuper Marl; the chief gypsum workings, however, lie a little way beyond the SE. limits of the Sheet.

The new map is issued in a 'Drift' edition only, as the Glacial deposits are nowhere extensive enough to obscure the boundaries of the 'Solid' formations.

J. J. H. TEALL,
Director.

Geological Survey Office,
28, *Jermyn Street, London,*
10*th October*, 1911.

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LIST OF SIX-INCH MAPS.

The following is a list of the six-inch Geological Maps included in the area, with the names of the surveying officers. MS. coloured copies of these maps are deposited for public reference in the Library of the Geological Survey and Museum of Practical Geology :—

QUARTER-SHEETS.

NOTTINGHAMSHIRE.

13. SW. (= Derby., 20 SW.), (small part), by J. B. Hill.
13. SE. (small part), by J. B. Hill.
14. SW. (small part), by G. W. Lamplugh.
14. SE. (small part), by G. W. Lamplugh and B. Smith.
15. SW., SE. (small parts), by B. Smith.
18. NW., NE., SW., SE., by J. B. Hill.
19. NW., SW., by G. W. Lamplugh.
19. NE., SE., by G. W. Lamplugh and B. Smith.
20. NW., NE. (= Lincs., 68 NE.), SW., SE., by B. Smith.
21. NW. (= Lincs., 69 NW.), (part), SW. (= Lincs., 69 SW.), (part), by B. Smith.
23. NW., NE., SW., SE., by R. L. Sherlock.
24. NW., SW., by G. W. Lamplugh.
24. NE., SE., by B. Smith.
25. NW., NE., SW., SE., by B. Smith.
26. NW. (= Lincs., 77 NW.), SW. (= Lincs., 77 SW.), by B. Smith.
28. NW., NE., SW., SE., by R. L. Sherlock.
29. NW., NE., by B. Smith.
29. SW., SE., by S. B. Wilkinson and B. Smith.
30. NW., NE., SW., SE., by B. Smith.
31. NW. (= Lincs., 85 NW.), (part), SW. (= Lincs., 85 SW.), (part), by B. Smith.

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FIGURES IN TEXT.

THE GEOLOGY OF

THE COUNTRY AROUND

OLLERTON.

CHAPTER I.

PHYSICAL FEATURES AND GEOLOGICAL STRUCTURE.

Area.

The map is outlined on a reduced scale in Fig. 1, p. 2, which will serve to show its limits. The area is almost entirely agricultural, but coal mining has begun to encroach upon its western side and will eventually spread eastward. The population is scattered in numerous villages or small towns, among which are Market Warsop, Edwinstowe, Ollerton, and Tuxford. The outskirts of the larger towns of Mansfield and Newark just enter the map, the former on its western margin and the latter near its south-eastern corner. The main line of the Great Northern Railway, between Newark and Retford, traverses the eastern side of the area; the Chesterfield and Lincoln branch of the Great Central Railway crosses it from west to east; and branches of the Midland Railway between Mansfield and Southwell and between Nottingham and Lincoln pass respectively through its south-western and south-eastern parts. The Great North Road, formerly one of the main stage-coach roads of the country and lately revivified by motor-car traffic, runs through it from Newark to Tuxford and beyond.

Drainage and Physical Features.

The whole area lies within the drainage-basin of the River Trent which flows as a navigable stream in a broad shallow valley through the eastern part of the district. Though still 35 miles distant from its outlet in the Humber, the river, owing to its low gradient, is slightly affected by the tide in the northern part of the map as far up as Girton Stakes. In its course across the map it is joined by a few small streams flowing eastward upon the dip-slope of the Keuper Marl, but the western half of the district is drained by tributaries which pass beyond the limits of the map before reaching the Trent. These are, the Greet in the south, and the Maun, Meden, and Poulter, which unite to form the Idle, in the north.

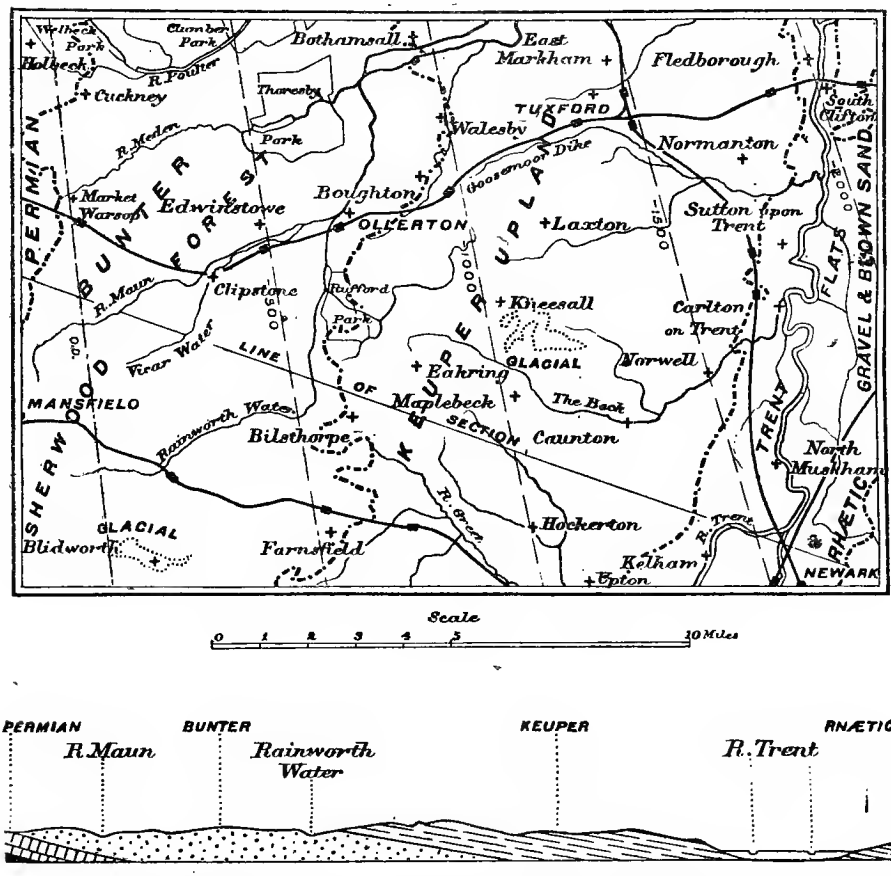
The area as a whole is a low dissected plateau, rising to slightly over 500 feet above sea-level in the south-western quarter, but

rarely reaching 300 feet in the northern part. The solid formations dip gently (at an angle rarely exceeding 2°) toward east-south-east, so that the lowest strata have their outcrop in the north-western part of the district and newer beds come on in succession toward the east. From differences in composition, each formation has its peculiar surface-features and soils, and the diversity of scenic aspect is thus an index to the geological structure.

FIG. 1.—SKETCH-MAP OF AREA IN SHEET 113, WITH DIAGRAMMATIC SECTION.

The broken lines are contours of the underground surface of the Coal Measures, the numerals giving the depth in feet below OD.

The vertical scale of the Section is much exaggerated.



CARBONIFEROUS.—The Coal Measures are known to underlie the whole area, as shown in the section at the foot of Sheet 113; but their emergence at the surface lies a few miles westward of its western border. Their presence underground is a factor of high consequence to the future development of the district.

PERMIAN.—The oldest rocks shown on the map are the Magnesian Limestones and Marls with Sands belonging to the

Permian system, which are exposed near the western border of the district in the valleys of the Maun, Meden, and Poulter, and around Holbeck Woodhouse. The Magnesian Limestone tract is too small and low-lying to display the typical characters of the formation, such as are seen in the country immediately to the west. The sands or soft sandstones intercalated with the Marls give rise to some steep ridge-like features in the neighbourhood of Holbeck Woodhouse.

Trias.—This system nearly monopolizes the map, the outcrop of its divisions occupying the whole area except the small tracts of Permian rocks just described and the still smaller patches of Lias at the south-eastern corner. It is divided into three formations, Bunter, Keuper, and Rhætic, of which the last is comparatively thin and unimportant. The first two are subdivided each into two parts by minor differences of composition.

Bunter.—This formation consists almost wholly of compact sands or crumbling sandstones, usually with a sprinkling of pebbles. It begins on the west in a bold escarpment which contains the highest ground in the map, ranging to slightly over 520 feet, and sinks gradually eastward in a long dip-slope which forms the dry sandy country of Sherwood Forest. The lower subdivision of the Bunter, known as the Lower Mottled Sandstone, occupies the outer slope of the escarpment, where it has a thickness of about 100-120 feet; it is composed mainly of loamy red, green-mottled sand. The upper and major subdivision is the Bunter Pebble Beds, consisting of a coarser, firmer sand or sandrock with many pebbles, which has a thickness of about 500-550 feet, and occupies all the Bunter country from the crest of the escarpment eastward. It is deeply trenched by the valleys of the Maun, Meden, and Poulter, which flow transversely across it from their sources in the older formations further westward; it is likewise furrowed by many shallower valleys which have once carried small tributaries to these streams but are now dry. The surface has thus a pleasantly diversified outline, and as it is in many parts richly timbered, and embellished by art in the great parks, the prospect is often delightful.

This is the district of the much-visited 'Dukeries'; the fine parks of Thoresby and Rufford lie wholly within the map, while Clumber Park and Welbeck Park are intersected by its northern border.

Owing to its permeability the Bunter affords underground storage for much of the rainfall over its broad outcrop, and it is consequently drawn upon for the water-supply of many towns. Within the area of the map there are large wells for the supply of Nottingham, Mansfield, Sutton and Kirkby in Ashfield, Southwell and Newark; and Lincoln now obtains its water from a site on the same belt barely 1½ mile beyond its northern margin. Where the Bunter sinks eastward beneath an impervious cover of Keuper, it is frequently saturated up to the surface and gives out springs, as at Farnsfield and Walesby; but usually the water-level lies at some depth.

Keuper.—Like the Bunter, the Keuper begins westward in a bold escarpment in which it attains its highest levels (up to

385 feet), and then sinks gradually eastward to the Trent valley. Like the Bunter, too, it has a subordinate lower division—the Waterstones—which is practically confined to the front of the escarpment, and a thick upper division—the Keuper Marl—which overspreads all the rest of the area. These two divisions of the Keuper together occupy more than half the map.

The Waterstones consist principally of thin flaggy beds of dull red or brown sandstone intercalated with red and green-mottled marl, and have a thickness of 150–250 feet. In this district a persistent belt of grey-green marl, 20-30 feet thick, forms their lowest portion, beneath which there is frequently a band of hard pebbly conglomerate, a few inches thick, resting directly on the Bunter. This marl forms a strip of clayey land along the foot of the escarpment. The thicker beds of sandstone above it frequently give rise to terraced features on the higher slopes, which, however, are rendered irregular by the impersistence of the individual beds. Small springs frequently issue from the sandstones, and have carved out deep coombs in the escarpment, of which there are good examples in Wellow Park.

The Keuper Marl is a mass of green-streaked red dolomitic clay, 600-700 feet thick, containing thin layers of hard dolomitic sandstone, known as 'skerry.' As the sandstone layers resist the weather better than the rest of the Marl, their outcrop is marked by shelf-like features which may be traced continuously for long distances. One of the lowest of these skerries usually upholds the crest of the Keuper escarpment, and the higher bands set in successively further eastward. Only the edges of these skerries can be shown on the map; but they are frequently close to the surface over a considerable portion of the Keuper dip-slope and protect the softer marls from denudation. The Keuper area is intricately dissected by ramifying groups of small valleys, which are often sharp-edged and steep-sided where the skerry-bands are numerous, but more open where the Marl lacks this support. In the broad valley of the Trent the Marl is concealed beneath alluvium and river-gravels, but it emerges again in places on the eastern slopes along the margin of the map, and forms a bold river-cliff at North Clifton.

Rhætic and Lias.—The Rhætic formation, with a small portion of the overlying Lower Lias, just enters the south-eastern corner of the district, rising sharply in a low escarpment east of Newark. The outcrop is continued northward for a little over two miles, but for part of this distance it is planed down and covered by old river-gravels. The Rhætic consists of about 30 feet of black and grey shales with some nodular limestone in the upper part. The portion of the Lower Lias coming within our district is made up of dark blue flaggy argillaceous limestones with partings of dark shale. The dark grey soils of the Rhætic and Lias are very different from those of the red Keuper country, so that the change at the boundary is readily appreciable.

The formations with which we have hitherto dealt follow each other in orderly sequence, so that their successive outcrops comprise well-defined belts of country, each with characteristics of its own. The sequence carries down the geological history of the

district to the beginning of the Jurassic period. In this area there is no record of later events until we come to the latest epoch in the geological scale—the Pleistocene, by which time the older strata had been brought by earth-movement and denudation nearly to their present condition and surface-configuration. The superficial deposits which occur here and there as an irregular covering to the solid formations enable us to follow somewhat imperfectly the history of the country during Pleistocene and recent times. Of these deposits the oldest are the Glacial drifts.

Glacial Deposits.—Considering the great masses of Glacial drift that there are in districts not far to the south and east, the amount in the present area is surprisingly scanty, particularly when it is found that the existing patches imply that the whole area has been covered by the Glacial ice-sheets. The patches are few in number and small in size; and they all occupy relatively high ground, having apparently been reduced to their present dimensions by the later paring down of the surrounding land. The largest is an irregular strip of boulder-clay and gravel about 1½ mile in length, which caps a narrow plateau of the Keuper Marl near Kneesall at an altitude of about 300 feet above O.D. A rather smaller ridge of similar materials occurs at Blidworth, rising to over 500 feet above O.D. Most of the other patches consist of Glacial flood-gravels which are found here and there in various parts of the district, usually near the margins of the present valleys. No Glacial drift has been recognized actually within the valley of the Trent in this part of its course, from which it may be presumed that the river has completely remodelled its valley since the ice disappeared from the district.

River Gravels and Alluvium.—The Trent has excavated a broad trench in the Keuper Marl, varying from a mile to three miles in width except for a short distance between North and South Clifton where the valley narrows to half a mile. The floor of the trench is overspread by river-gravel and alluvium, and constitutes the tract termed the Trent Flats, on which the river itself is confined in a sinuous channel overpassed only by exceptional floods. The tracts of river-gravel rise as a rule above present flood-level; they were probably deposited at, or soon after, the close of the Glacial epoch, when the river was of greater volume than now. The string of villages along the flat have their sites on these old gravels which afford excellent agricultural soils. The oldest gravel forms a terrace rising 10 to 20 feet above the flat on the east side of the river north of Newark.

The valleys of the Meden, Maun, and Greet have likewise their local gravel-flats rising a little above the recent alluvium, but these are mostly too small to be shown separately on the map. Some of the small streams of the Keuper country are charged with mineral matter in solution, giving rise to the deposition of Calcareous Tufa on their alluvial flats. Tracts of this material are mapped in the valleys running north-east and south-east from Tuxford, and in the Caunton valley.

The slopes of the Trent valley north of North Collingham are lined in places by a covering of loose Blown Sand, which appears

to have drifted from the adjacent river-flat. This sand is found principally on the eastern side of the valley, indicating that westerly winds have been predominant in its production.

G. W. L.

The formations represented on the map are summarized in the following table:—

TABLE OF FORMATIONS.

Superficial Formations.

	Recent	Blown Sand.	
		Alluvium and Tufa.	
PLEISTOCENE ...	Post-glacial	River Gravel.	
	Late-glacial	Older River Gravel.	
	Glacial	Boulder Clay, with Sand and Gravel.	

Solid Formations.

JURASSIC ...	Lower Lias	Thin limestones with shale partings.	
TRIASSIC... ...	Rhætic	Black and grey shales with nodular limestone.	
	Keuper Marl	Red and variegated marls with thin sandy bands (skerry).	
	Keuper Waterstones ...	Thin flaggy sandstones and marl.	
	Bunter Pebble Beds ...	Soft sandstone or sandrock with pebbles.	
	Lower Mottled Sandstone (Bunter).	Red and variegated soft sandstone.	
PERMIAN ...	Upper Magnesian Limestone.	Dolomitic limestone.	
	Middle Marls and Sands	Red marls and soft sands.	
	Lower Magnesian Limestone.	Dolomitic limestone.	

CHAPTER II.

UPPER CARBONIFEROUS:—COAL MEASURES.

Underground Extent.

Although the Coal Measures do not appear at the surface, they are known to form the floor of the Permian rocks in the workings of the Warsop Main and Mansfield collieries, and in the Bevercotes boring. It is generally admitted that they were reached in a boring at South Scarle about half a mile north-east of North Collingham. They have also been proved in several borings and sinkings a short distance beyond the northern and southern limits of the map.

The surface on which the Permian rocks were deposited presents an even slope directed nearly due east, which falls at a nearly uniform rate of 110 feet per mile in the south of the area, and at a rate of 120 feet per mile in the north. Given, therefore, the depth to the Coal Measure surface relative to sea-level at a few points, such as at Warsop Main Colliery, Mansfield Colliery, and in the borings to the south and north, it is possible to represent the general slope of the buried Coal Measure surface by means of contour lines, as indicated on the small sketch-map (Fig 1, p. 2). A considerable thickness of Coal Measures was removed by denudation before the Permian rocks were deposited. The amount thus lost was greater at Mansfield Colliery than at Warsop Main Colliery (Fig. 2, p. 8). In both cases the Upper Coal Measures of Oxton and Thurgarton[1] and a part of the Middle Coal Measures are missing.

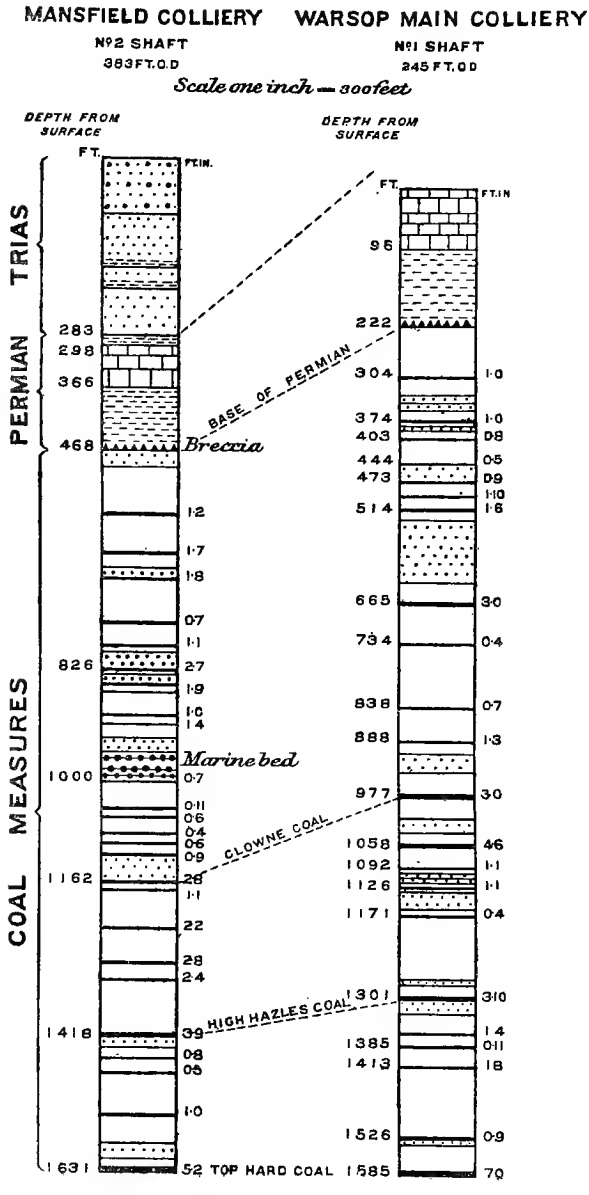
The character of the Coal Measures is shown by the records of the Mansfield and Warsop Main collieries (Appendix I., pp. 74, 78). The seam of coal worked at both localities is the one known throughout Nottinghamshire and Derbyshire as the Top Hard, famous as furnishing in different parts of the same seam a Steam, House, Gas, and Manufacturing Coal. A comparison of the records shows a greater amount of sandstone at Warsop than at Mansfield—a noteworthy increase which is in agreement with what takes place among the arenaceous members in the coalfield to the west. The general thickening of the measures northward also becomes evident on comparing the distance between the Clowne Coal and High Hazles Coal, and between the last-mentioned seam and the Top Hard Coal in the two sections.

Marine Bed.

The most distinctive and interesting part of the sequence occurs 631 feet above the Top Hard Coal in the shaft at Mansfield Colliery. At this horizon a thin coal (7 inches) with 2 feet 4 inches of greyish-blue shale (blue bind) above, is succeeded by 36 feet 5 inches of pale-blue shale resting on a hard dark-blue

[1] 'Geology of Newark and Nottingham,' *Mem. Geol. Surv.*, 1908, pp. 16, 17.

FIG. 2.—SECTIONS OF COLLIERY SHAFTS. (*W. Gibson.*)



argillaceous limestone (cank). Many of the genera contained in these beds are indicative of marine conditions, as will be seen from the following list[1] :—

Crinoid columnals
Spirorbis sp.
Chonetes laguessiana *de Kon.*, *mut.0 Hind*
Lingula mytiloides *J. Sow.*
Productus (spines)
Ctenodonta lævirostrum (*Portl.*)
Myalina *cf.* compressa *Hind*
Nucula gibbosa *Flem.*
Nuculana attenuata (*Flem.*)
Posidoniella laevis (*Brown*)
,, sulcata *Hind*
Pseudamusium fibrillosum (*Salt.*)
Pterinopecten carbonarius *Hind*
,, papyraceus (*J. Sow.*)
Euphemus *cf.* urei (*Flem.*)
Loxonema?
Glyphioceras bilingue? (*Salt.*)
,, phillipsi? *Foord and Crick*
,, sp.
Orthoceras *cf.* asciculare *Brown*
,, sp.
Pleuronautilus sp.
Cytherella sp.
Acanthodes sp.
Coelacanthus elegans *Newb.*
Elonichythys egertoni (*Egert.*)
Listracanthus wardi *A. S. Woodw.*
Pleuroplax rankinei (*Hanc. and Atth.*)
Rhizodopsis sauroides (*Will.*)

The most abundant fossils are species of *Nucula*, *Pseudamusium*, *Pterinopecten*, *Posidoniella*, and Goniatites; species, it will be observed, found in the beds below the Millstone Grits. *Lingula* occurs in profusion. The genera *Carbonicola*, *Anthracomya*, and *Naiadites*, common in the beds above and below, are not represented, and their absence shows that whatever may have been their habitat they were unable to live side by side with purely marine organisms. There are also single examples of *Nucula*, *Allorisma*, and *Aviculopecten* which are considered by Dr. Wheelton Hind to represent new species. In addition, a radially-ribbed shell showing peculiar surface sculpture has been provisionally referred by Mr. R. B. Newton to *Spiriferina*.

Previous to the discovery of this interesting bed at Mansfield the presence of marine shells in the Middle Coal Measures above the Top Hard had been noted at Gedling Colliery when the material from these shafts was examined during the re-survey of the Derbyshire and Nottinghamshire Coalfield,[2] but the fauna was restricted to *Lingula* and *Orbiculoidea*.

Since its discovery at Mansfield the zone characterised by the same sequence and some of the fossils has been found at Oxton,[3]

[1] The fossils were determined for the most part by Dr. Ivor Thomas. *See* 'Summary of Progress for 1905.' *Mem. Geol. Surv.*, 1906, pp. 76–77.
[2] 'Summary of Progress for 1902,' *Mem. Geol. Surv.*, 1903, pp. 13–17.
[3] 'Geology of Newark and Nottingham,' *Mem. Geol. Surv.*, 1908, p. 17.

and in Yorkshire the bed has been noticed by Messrs. Culpin[1] and Dyson[2] in the measures above the Barnsley Coal (=Top Hard) in the neighbourhod of Doncaster to contain even a richer fauna than at Mansfield. It was passed through in the shafts of Manton Colliery, and has been met with in other borings north and south of the present area. The thin coal invariably present at the base affords a remarkable instance of a seam extending over a wide area, the formation of which was closely followed by a set of conditions very unlike those under which most of the coals are considered to have been formed.

The prolific and varied fauna of the marine bed, and its widespread distribution in Nottinghamshire and Yorkshire, can only be taken as indicating an extensive and possibly a prolonged depression which brought back the Carboniferous sea and with it many of the life-forms of the Lower Carboniferous period. The assemblage, however, is characteristic of the Middle Coal Measures, and is so reminiscent of that below the Gin Mine Coal, occurring high up in the Middle Coal Measures of North Staffordshire,[3] as to suggest that the depression extended across the Penine region into the west.

Apart from the interesting occurrence of the specialised fauna in this zone, the lithological characters of the shales and of the argillaceous limestone distinguish it from any other stratum occurring above or below the Top Hard Coal. The zone, therefore, forms a reliable index of position in an otherwise monotonous sequence, and on this account should prove of service in borings and sinkings.

Future Development.

In the extension of the Nottinghamshire and Derbyshire Coalfield under the Permian, the seam sought after is invariably the Top Hard Coal. In the shafts of the Warsop Main Colliery this coal is at a depth of 1,333 feet below Ordnance Datum and 1,356 feet beneath the base of the Permian. At Mansfield Colliery the Top Hard was found at a depth of 1,241 feet below Ordnance Datum, and 1,158 feet beneath the base of the Permian. In the workings of the Mansfield Colliery the general inclination of the Top Hard is 3 degrees (276·7 feet per mile) to the north-east.[4] If this dip continues in amount and direction the Top Hard Coal would lie beyond the depth (4,000 feet) of practical working over the area bordering the Trent. In the concealed coalfield proved to the south and north of the present area the strike remains fairly constant, but the dip invariably decreases to the north-east until it is only a little over one degree (92·16 feet per mile). If this lowering of dip takes place to the east and north-east of Mansfield Colliery the Top Hard Coal may extend at workable depths

[1] *Proc. Yorks. Geol. Soc.*, vol. xvi., pt. iii., 1908, pp. 321–326, and *ibid.* vol. xvii., pt. i., 1909, pp. 75–76.

[2] *Rep. Brit. Assoc. for 1910* (Sheffield Meeting), 1911, p. 610

[3] 'Geology of the North Staffordshire Coalfields' *Mem. Geol. Surv.*, 1905, p. 320.

[4] The general inclination is subject to local variations. Thus, at the Warsop Main Colliery the shafts appear to have been sunk on a dome of Coal Measures which dip to all points of the compass at a rate varying between 3 and 5 degrees.

up to and beyond the eastern margin of the map. The possibility of pre-Triassic faulting or of a rise of the measures to the east must not be lost sight of; however, so far as the evidence points in the adjacent areas, the faulting would not be sufficiently large to depress the Top Hard below workable depths, but a slight uprise would be enough to bring the Top Hard against the Permian within the limits of the map.

Any attempt to find the depth to the Top Hard Coal, based on an assumed dip and the absence of faulting can have little value, but there is no probability that in the area bordering the Trent in the present map the seam, where it exists, will anywhere exceed 4,000 feet in depth from the surface. Future explorations need not, therefore, be deterred by the question of depth, but it is impossible to say what will be the thickness and quality of the coal.

W. G.

CHAPTER III.

PERMIAN.

General Account.

Although the outcrop of the Permian strata in this map is confined to a small expanse near the western margin, it is known from deep borings that the formation underlies the Triassic rocks throughout the area, and that it becomes thicker in its underground extension eastward. It likewise thickens northward along the outcrop.

The classification of the Permian into subdivisions is rendered difficult by the local variations of its members both at the outcrop and underground. The subdivisions recognised at the surface within the limits of this sheet are the Lower Magnesian Limestone, the Middle Marls, and the Upper Magnesian Limestone. In addition to these, however, still lower subdivisions—the Marl Slates, and the basal Breccia—have been passed through in some borings (pp. 73, 74); and it seems probable also that the Upper Marl (which overlies the Upper Limestone) was proved in one of them (p. 73).

From the sections given in Appendix I. it will be seen that the total thickness of the Permian in the Mansfield (Crown Farm) Colliery shaft is 184 feet (p. 74), while at the Warsop Colliery 4½ miles farther north, although the section starts below the top of the formation, the incomplete thickness is 222 feet (p. 78). Farther east, in the Bevercotes boring, the thickness of the Permian is increased to about 417 feet (p. 73), and in a boring at South Scarle, a mile beyond the eastern limit of the map, near North Collingham, it proved to be 519 feet.[1] In the Thurgarton boring, in the Trent valley, 4 miles beyond the southern border of the map, the thickness of the formation was only 93 feet.[2]

G. W. L.

Lower Magnesian Limestone.

This formation is sparingly represented on the western margin of the map, its superficial extent not exceeding two square miles. Its principal outcrop lies between Market Warsop and the edge of the sheet.

The portion which enters the sheet is the eastern margin of the main outcrop which extends to the Bolsover escarpment. It has been pointed out[3] that the whole belt may be roughly divided into three zones, the central portion being characterised by a high degree of false-bedding and the presence of domes of compact dolomite, while the upper and lower zones have a more regular and thin-bedded flaggy structure. It is the upper zone only that

[1] 'Geology of the Country around Lincoln,' *Mem. Geol. Surv.*, 1888, pp. 194–5.
[2] 'Geology of the Country between Newark and Nottingham,' *Mem. Geol. Surv.*, 1908, p. 114.
[3] 'Summary of Progress for 1908,' *Mem. Geol. Surv.*, 1909, p. 18.

is represented in this sheet, and thin flaggy dolomite is the prevailing type, although subject to much variation.

The rock is composed mainly of dolomite crystals with a variable but usually small proportion of sand, and generally with a certain amount of free calcite. The crystalline texture is commonly visible, but fine compact varieties occur in which the lens is necessary for its detection. When fresh the colour of the rock is pale grey or cream, but on decomposition hues of yellow, orange, pink, and red prevail. Its bedding structures are markedly diverse, and suggest that its individual grains have been swept as such over the sea-bottom and deposited as a true sediment. The development of arches or elongated domes of original deposition is an interesting feature, but not strongly developed in the limits of this sheet. The Lower Magnesian Limestone contains but few fossils, and none have been detected in this area. It varies considerably in manner of decomposition, the soil in some places being thin and abundantly strewn with dolomite fragments, while elsewhere there may be a depth of several feet of dolomite-sand. It frequently, however, forms a stiff soil, approaching in tenacity the clay-soils of the overlying Permian Marl.

The surfaces of the individual flags are often hackly, with projections which connect the adjacent beds, but this interlocking structure is probably secondary.

On account of its irregularity of structure it is exceedingly difficult, as pointed out by Aveline,[1] to ascertain the true dip. All that can be said for certain is that it inclines slightly to the eastward, and the average dip may be about 2°. J. B. H.

DETAILS.

On the north edge of Cuckney Hay Wood, close to the south bank of the mill stream, there is a dolomite quarry. The rock is compact and disposed in regular beds which dip eastward from 5° to 10°. The main bands are from 6 inches to a foot in thickness, and the surfaces are very hackly. Some of the joints are coated by a red marly substance. It is pale buff in colour, but often weathers to deep orange. This dolomite is almost pure, yielding practically no residue on treatment with heated hydrochloric acid.

A quarry adjoining the mineral railway a third of a mile ENE. of Warsop Main Colliery shows rock of a more irregular type. The texture is generally very fine and compact, although there are bands with honeycomb structure, presenting a brecciated aspect. The structure is very irregular and shows the arching or doming previously alluded to, and the dip is mainly to the north. In parts of the quarry good flags can be raised, over 6 inches in thickness, with the interlocking suture structure conspicuous on their surfaces. The coarser honeycombed bands contain numerous thin streaks of impure limestone which effervesce freely with cold hydrochloric acid, and weather brown. There are also rounded inclusions of reddish brown sandstone that were probably calcareous, and the rock is interrupted by pipes, partly infilled by shaly material and partly by banded calcareous sandstone.

In an old quarry, ¼ mile SW. of Askew Spa, there is an excellent section of a large dome of dolomite flanked on either side by flaggy beds. The angle of slope of the dome is about 20°. In this neighbourhood the dolomite

[1] 'Explanation of Sheet 82 S.E.,' 2nd edition ; *Mem. Geol. Surv.*, 1879, p. 17.

has been extensively quarried, especially at the localities known as ' Hills and Holes,' the rock being flaggy and more or less regular. The gorge below Hammer Water Bridge shows a natural section of the dolomite.

To the south of Hammer Water Bridge the valley of the Meden is floored by dolomite and the plain at the foot of Whinny Hill is on the same rock. Further south a small loop of dolomite enters the map along the dry valley at Hallam's Grave and is exposed in a small disused quarry which shows a few feet of the rock overlain by red marly sandrock. The sandrock represents the Lower Mottled Sandstone and has a slightly different dip from that of the dolomite.

Still further to the south the valley of the Maun brings in another tongue of dolomite on the outskirts of Mansfield, where, on the western edge of the map, a millpond which is probably on the site of an old quarry, affords a section of about 20 feet of yellowish dolomite. The "Red Sandstone" of Mansfield, which underlies the yellow dolomite to the west, is not here seen. J. B. H.

Middle Marls and Sands.

This series, which immediately succeeds the Lower Magnesian Limestone, is well developed between Cuckney and the northern edge of the map, where its outcrop is over a mile in width. To the south of Cuckney the outcrop shows a sudden contraction which is only in part accounted for by the fault aligning the valley between Cuckney and Langwith Mill. South of the fault the series is reduced to a thin band which dies out at Minster Wood, about a mile south of Langwith Mill; and the Lower Magnesian Limestone from that point to Hammer Water Bridge, and slightly beyond it (a distance, as the crow flies, of $1\frac{1}{4}$ mile), is in contact with the Lower Mottled Sandstone. Beyond this gap the marls set in again between the Lower Magnesian Limestone and Lower Mottled Sandstone west of Leeming Lane, and continue until they swing out of the map in the vicinity of Whinny Hill.

This series presents two lithological types according as the sand or the clay predominates. As pointed out by Aveline, the sandy type only comes on in force to the north of Cuckney, where, in the country between Holbeck Woodhouse and Welbeck Park, both types are present. The dividing line between the types in this ground may be taken approximately as connecting South Carr with Woodhouse Hall. On the east of it the series is almost entirely represented by red clay and forms smooth low-lying land, while to the west sandy beds predominate, forming higher ground rising sharply above the clay tract and culminating in the ridge between Collingthwaite and Holbeck Woodhouse, which is capped by two outliers of the overlying Upper Magnesian Limestone. The red clay contains thin bands or skerries of grey or red dolomitic sandstone, which range from an inch to a foot in thickness and contain about an equal proportion of sand and dolomite, together with a little calcite which acts as a binding cement. Similar bands are present in the sandy series, and they serve to distinguish the Lower Mottled Sandstone of the Bunter, which does not contain them, from the Permian beds when other evidence is wanting. Another useful distinction between the formations in this region is the absence of marl bands in the Lower Mottled Sandstone, though in the district to the south this

distinction appears to be lost, as Mr. Sherlock has noticed the intercalation of marl in the basement beds of the Bunter.[1]

After making every allowance for the attenuation of all the Permian beds in a southerly direction, which in itself might explain the disappearance of the Upper Magnesian Limestone in the Nottingham district, there appears to be hardly any doubt, so far as the district between Welbeck Park and Sookholme is concerned, that there is an unconformity between the Bunter and the Permian (*see* below p. 16). J. B. H.

DETAILS.

An excellent section of the sandy series is seen in the road-cutting leading west from Holbeck Woodhouse where, as described by Aveline, "there are between 30 and 40 feet of soft red sandstone in thick beds, except about 6 feet at the centre, which consists of thin alternations of sandstone and marl."[2] Another section of red sandy beds and marl is seen in the lane-section ½ mile NNW. of Collingthwaite. In both exposures bands of dolomitic sandstone are present, similar to those occurring in the marls of Welbeck Park. Like the sandstones amid which they occur, these bands are usually much decomposed and the calcite cement has been largely removed. Besides distinct beds of sandstone and marl, the series also includes bands composed of a varying admixture of sand and clay.

The sands probably occur as lenticles which do not appear to occupy a definite position in the series. On the west the entire sequence between the Lower and Upper Magnesian Limestones consists of the mixed series of sands and marls, while on the east, in Welbeck Park, the marls are nearly free from sand, so that the occurrence of the marls points to a lateral change. Aveline pointed out that the Upper Magnesian Limestone is here overlapped by the Lower Mottled Sandstone, as otherwise it should again outcrop to the eastward between the latter and the Permian Marls.[3] This evidence for the overlap is confirmed by the further encroachment of the Lower Mottled Sandstone on the belt of marls and sands which culminates in the Warsop district where, as already mentioned, the Lower Mottled Sandstone lies directly on the Lower Magnesian Limestone. The overlap is most evident in Welbeck Park, where the boundary of the Lower Mottled Sandstone swings to the south-west past Bunkers Hill, and at Cuckney has completely overlapped the marly portion of the series, and is in contact with the sand-and-marl subdivision, the breadth of outcrop of the series having been reduced by the width of the missing portion represented by the marls of Welbeck Park. Immediately south of the Poulter Valley at Cuckney the diminution of the band is still more sudden, but this is doubtless accounted for largely by the fault to which allusion has already been made.

In the millstream south of Langwith Mill the mixed sands and marls are clearly seen, but from Cuckney Hay Wood to Minster Wood they must be very attenuated, the evidence for their presence being found only in two small pits. From this point to a little south of Hammer Water Bridge they are either entirely unrepresented or are too thin for detection. Moreover, in this tract between Langwith Mill and Hammer Water Bridge the Lower Mottled Sandstone retains its dominant arenaceous characters throughout, so that the marls would not be difficult to detect if present. A large sandpit, entirely in sand, occurs, for instance, close to the main road a little south of Langwith Mill within a hundred yards of the marl series, while a much larger pit, about 25 feet in depth, occurs within a similar distance of the Lower Magnesian Limestone at Gipsy Lane (¾ mile NE. of Warsop Main Colliery). The latter sandpit at its base must be very close to the surface of the Lower Magnesian Limestone.

[1] 'Geology of Newark and Nottingham,' *Mem. Geol. Surv.*, 1908, p. 26.
[2] 'Explanation of Sheet 82 SE.,' 2nd edition, *Mem. Geol. Surv.*, 1879, p. 18.
[3] 'Explanation of Sheet 82 SE.,' 2nd edition, *Mem. Geol. Surv.*, 1879, p. 19.

It contains no clay, although a few of the sandy bands have an argillaceous matrix which imparts sufficient consistency to admit of its removal in slabs, whereas the red sand is mainly incohesive. There are no traces in this section of the dolomitic sandstone skerries common in the marl and sandy marl series, and nothing that would suggest any relation with the latter.

However, although absent in this locality below the Bunter escarpment the marls are represented by outliers on the dolomite a little further to the west, one of which just enters the margin of the map half a mile north of Sookholme. A little further east an outlier of Lower Mottled Sandstone rests in part directly upon dolomite, while in places there is a thin band of marl interposed between them; but the marl here must be much thinner than in the large outlier to the west. This shows that the marl is thinning towards Hammer Water Bridge, which accounts for its absence in that quarter. The evidence of the Bunter outlier suggests, moreover, that there is not only an overlap but an unconformity.[1]

Red clay has been raised in various pits in Welbeck Park and it has also been deeply trenched in places on the boundary of the deer park. Immediately to the north of Tile Kiln Wood there are two pits in the red marl. In the most southern of these are interstratifications of dolomitic sandstone bands, grey to red in colour, ranging up to two inches in thickness, but the section is somewhat obscure and the lower portion is covered with vegetation. In one specimen of the sandstone, treated with acid, rather more than half of the rock consisted of fine angular sand, mainly quartz, with some cryptocrystalline silica, probably chert, a little felspar, and a few grains of heavy minerals, including zircon, and flakes of chlorite.

A good section of the marls is seen in the trench connecting Park Lodge ($\frac{1}{4}$ mile NW. of Bunkers Hill) with Battlefield Plantation a little to the north. Here the red clay is capped by a little drift consisting of a foot or so of marl mixed with pebbles, overlying a thin bed of gravel.

On the margin of Battlefield Plantation, slightly to the south-west of Greendale Oak, a clay-pit has been sunk on the boundary of the Permian marl, and shows its junction with the overlying Lower Mottled Sandstone.

A large disused clay-pit at South Carr was formerly worked for bricks, but is now overgrown. Numerous blocks of grey dolomitic sandstone are strewn on the bottom of the pit, and it is evident that these bands are here well developed, some of the blocks reaching a foot in thickness; a specimen tested contained angular sand to the extent of at least half the rock.

The best sections in the mixed sand and marl belt are those already alluded to in the road-cutting at Holbeck Woodhouse, and in another about a quarter of a mile south of that locality. A typical red sandstone from the former place was tested and found to contain a little dolomite. Another specimen, more evidently dolomitic, proved to be similar to the bands of dolomitic sandstone from the marl series in Welbeck Park, though much more decomposed. It contained a good deal of dolomite, while the insoluble residue consisted mainly of angular quartz, with a fair amount of chert, and likewise some ilmenite gone over into leucoxene, and some zircons.

The series also outcrops near Cuckney on the main road leading to Collingthwaite, and has been dug in shallow pits on the north-west side of the Poulter valley.

To the south of the Poulter valley the red marl is seen in a small pit about 700 yards north of Warsop Main Colliery. In the outlier on the western edge of the map it is exposed in a deep ditch immediately south of the Great Central Railway. To the south-east of that locality it is seen beneath the alluvium of the River Meden where it apparently joins a thin

[1] Dr. R. L. Sherlock, however, in a recent paper, expresses the opinion that the Bunter is conformable to the Permian and that the upper part of the Permian series in the northern district is equivalent to the lower part of the Bunter further south; *see* 'The Relationship of the Permian to the Trias in Nottinghamshire,' *Quart. Journ. Geol. Soc.*, vol. lxvii., 1911, pp. 75–117.

and discontinuous strip between the Lower Magnesian Limestone and the outlier of Lower Mottled Sandstone. Further down the stream, however, it cannot be detected in that position and if present must be reduced to an insignificant shred.

To the south of Hammer Water Bridge the marls are again seen in the banks of the brook flowing through the grounds of Park Hall. Marl is also met with at the sewage works west of Whinny Hill where it had been excavated in making tanks. Mr. Sherlock states that the marl appears to be absent near Mansfield but may be represented by the very marly sandrock which overlies the Magnesian Limestone, *e.g.*, at Hallam's Grave. J. B. H.

Upper Magnesian Limestone.

This portion of the Permian system is only represented by the two small outliers of dolomite at Collingthwaite and Holbeck Woodhouse to which allusion has already been made. Their existence at these places was first recognised by Aveline,[1] and they are at the present time very poorly exposed.

The rock was formerly quarried near Collingthwaite, but can only now be traced by the flaggy fragments plentifully scattered in the soil. Traces of fossils were observed in some of the fragments, which are generally pitted and decalcified. A specimen tested with acid was found to be singularly pure and to contain a smaller residue than any of the Lower Magnesian Limestones tested from this district. The super-position of the Upper Limestone on the Middle Marls and Sands is clear, and the dip as seen in the latter beds at Holbeck Woodhouse is slightly to the westward. The absence of the Upper Limestone farther to the east, where the marls have resumed their normal easterly dip, appears to imply, as pointed out by Aveline, that the band has been there overlapped by the Lower Mottled Sandstone. Its thickness in the outliers is uncertain, but is probably not above 10 or 12 feet.

J. B. H.

[1] 'Explanation of Sheet 82 SE.,' 2nd ed., *Mem. Geol. Surv.*, 1879, p. 18.

CHAPTER IV.

TRIAS:—BUNTER.

General Account.

The outcrop of the Bunter covers fully one-third of the map. The formation is divided into two unequal parts, the Lower Mottled Sandstone below, and the Pebble Beds above, the latter occupying by far the greater part of the outcrop. The Upper Mottled Sandstone which in Lancashire overlies the Pebble Beds, has no representative in Nottinghamshire.

The relations of the Bunter to the beds below have been dealt with in the preceding chapter so far as the north-western part of the district is concerned. Farther southward the relations are not quite clear, as the Lower Mottled Sandstone becomes increasingly marly in its lower portion, and the junction with the Permian Marl, where seen in the adjacent area in Sheet 112, has the appearance of a conformable passage.

At the upper boundary of the Bunter there is a marked lithological difference between the Pebble Beds and the Keuper Waterstones, and a slight discordance in the strike of the two formations suggests some degree of unconformity or overlap between them.

Although the Bunter outcrop is six miles wide, the formation is only about 680 feet thick. The Lower Mottled Sandstone rises gently from the Permian flat, but the incoming of the harder sandrock is marked by bolder features culminating in the escarpment of the Pebble Beds, which however is much broken by deep valleys. From the crest of the escarpment, on which lies the highest ground in Nottinghamshire, the surface rises and falls irregularly in flowing contours but with a persistent descent eastward in accordance with the dip of the strata, so that where the Bunter passes beneath the Keuper, the ground is usually about 200 feet lower than at the escarpment.

Owing to the prevalence of cross-bedding the dip of the Bunter cannot be determined directly, but it may be calculated from the relative levels at the outcrop and in borings. In this way the average eastward dip over the area is found to be 105 feet per mile, or slightly over 1 degree.

The thickness of the formation does not appear to vary much in this area, as it was proved by a boring at Kelham on the south margin to be 671 feet, and by a boring at Bevercotes near the northern edge of the map to be 682 feet. It is extremely difficult to distinguish the subdivisions in the borings, but at Kelham the lower 200 feet seem to be of Lower Mottled Sandstone type, while at Bevercotes only about 114 feet, and at Mansfield Colliery (Crown Farm) only 112 feet could be assigned to this division.

The Lower Mottled Sandstone is composed in the lower part of fine red silty sandrock with many lenticles of red marl. In the upper beds the marl is less abundant and the sandrock is of

coarser grain and more massive character. The Pebble Beds differ in being still coarser in grain and in containing well-rounded pebbles which occur in a sporadic manner throughout the rock or are grouped into strings or gravelly patches.

Occasionally the junction of the Lower Mottled Sandstone with the Pebble Beds is sharply marked, as was very well seen in 1905 in one of the pits south-east of Mansfield (*see* Plate II); but more frequently there is a gradual and indefinite passage between them. Rounded pebbles are nearly absent from the Lower Mottled Sandstone, but thin breccias of small angular fragments sometimes occur in their lower portion. Cross-bedding is also less marked than in the Pebble Beds. R. L. S.

Lower Mottled Sandstone.

In the northern part of its outcrop this division of the Bunter covers a belt of about a mile in breadth running from Welbeck Park southward past Norton, Cuckney and Warsop, and narrowing to not much over half a mile where it passes out of the map near Mansfield. In the valleys of the Meden and Maun it extends eastward for a greater distance owing to the removal of the overlying Pebble Beds by the erosion of the rivers. As a rule it rises gently from the Permian low ground to the west, but in some places it makes a bold feature, as in the tract lying between Cuckney Hill and Collier Spring. In this district it is generally of a bright red colour, and the characteristic green-mottling from which it takes its name is practically absent. It consists of sand and soft sandrock, usually of fine texture and somewhat loamy, which are extensively raised in several localities for moulding-sand. Small seams and lenticles of marl are occasionally present, particularly in the lower part of the series, and these become more abundant as we go southward. Large pebbles are of rare occurrence, but narrow seams of small angular and partly rounded rock-fragments are frequently present.

The relations of the Lower Mottled Sandstone to the underlying Permian strata have already been dealt with (pp. 15, 16, 18). In the neighbourhood of Welbeck Park, where the sands contain very little marl, their base can be followed without difficulty; but in the Cuckney district where they overlie the Permian sands and marls the precise boundary between the two formations is more difficult to trace owing to the similarity of the sands.

J. B. H.

DETAILS.

Owing to the general softness of the beds, good natural sections of Lower Mottled Sandstone are rare, but it is well exposed in numerous pits. A large pit, ¾ mile NE. of Warsop Main Colliery, which goes nearly to the base of the formation, has a working face about 300 yards in length and 25 feet in depth. The section consists in the main of incoherent red sand with angular grains, singularly free of pebbles; but there are also lenticles and bands of micaceous marly sand sufficiently coherent to be removed in slabs. There is no true clay in the section. The dip is east, at about 2°, and there is cross-bedding in the same direction at a higher angle.

A sandpit one-third of a mile NNE. of Warsop station reveals bright red sand, fairly coarse in texture, in which small pebbles of rounded

quartz are scattered rarely, and an isolated pebble, about 4 inches in size, was seen. The sand here included some small lenticles of red clay, a few of which lie along the planes of false bedding. The dip is from 2° to 3° to the east, with false bedding in the same direction but steeper. The sand, as in the last pit, is capped by a few feet of pebbly drift with an irregular base.

Another sandpit near the roadside in the north-east corner of Cuckney Hay Wood, within 100 yards of the Permian margin, has already been alluded to (p. 15). It shows very evenly stratified bright red sand with a few small scattered pebbles, but no trace of clay. The bedding is nearly flat, with a very slight easterly dip. The sand has also been quarried further up the valley at Cuckney, but the pit is no longer used.

Among other small exposures in the area north of Warsop, there is a section of red sand with a few scattered pebbles along the main road between Langwith Mill and Cuckney; and in the latter locality it is exposed in a steep bank of the Poulter at St. Mary's Church; also, in the lane about 330 yards SE. of the Church, where it is in a more consolidated condition. J. B. H.

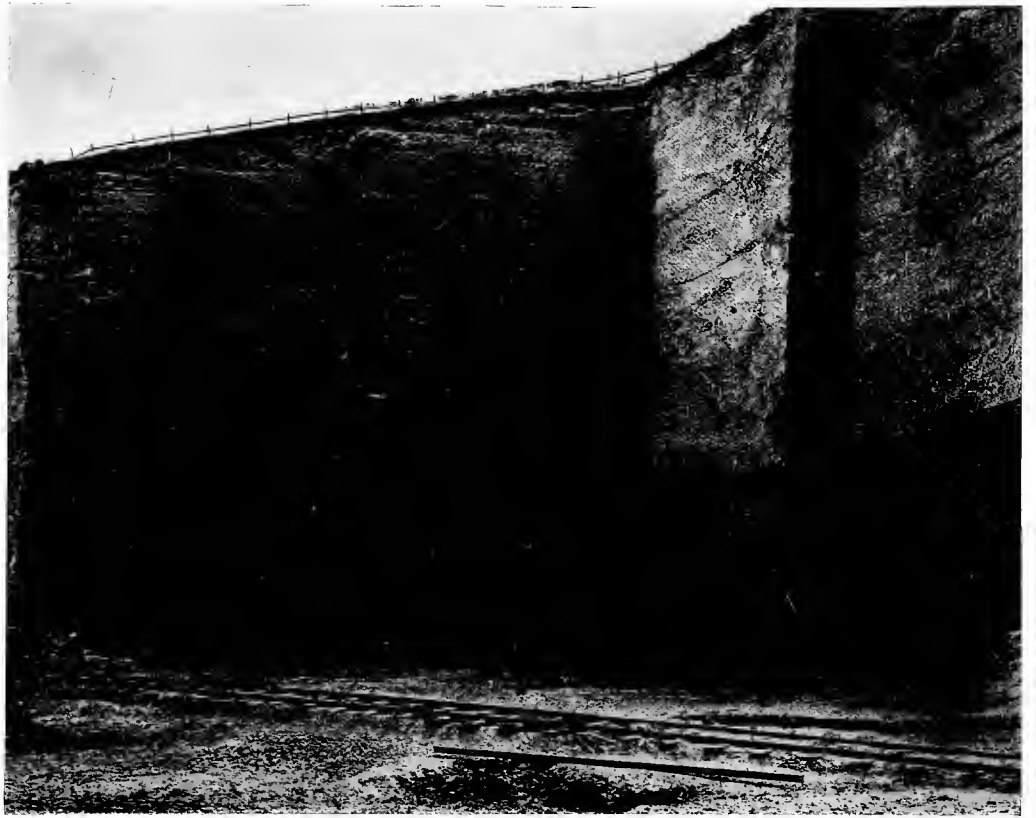
In the portion of its range south of Warsop, the best section of the Lower Mottled Sandstone is that revealed just at the western margin of the map near Mansfield, in the sandpit of the Mansfield Sand Co., Ltd., shown in Plate II. The pit is about 75 feet deep, of which the lower 30 feet belongs to the Lower Mottled Sandstone. In this section the junction of the Pebble Beds with the Lower Mottled is remarkably sharp, with indications that the lower beds have been eroded, as small fragments of them occur as pebbles in the basal part of the Pebble Beds. The Lower Mottled Sandstone is here a deep red, fine-grained, somewhat marly sandrock which is quarried for moulding sand. Certain gritty bands occur, especially at the bottom of the pit, which seem quite similar to the breccia bands noticed in the formation further south (*see* 'Explanation of Sheet 125,' p. 130). Films of red marl indicate the nearly horizontal bedding.

A disused sandpit, about 75 feet deep, on the south side of the Mansfield and Southwell branch railway, close to the west margin of the map, and another pit immediately north of the railway, give sections very like the one just mentioned and reveal a similar sharp junction of the Lower Mottled Sandstone with the Pebble Beds. But in another pit, little more than 100 yards north of the last, on the high road from Mansfield to Farnsfield, there are no such indications of local erosion at the junction.

Sections of the Lower Mottled Sandstone are plentiful in the eastern suburbs of Mansfield, but for the most part they lie west of the present area. The rock is exposed, however, to a depth of 15 feet in a section 200 yards west of the Old Windmill; and on the Farnsfield road, 300 yards NW. of the windmill, there is a section showing 7 feet of disturbed pebbly and marly sand over 7 feet of coarse reddish sandrock resembling Pebble Beds, but without any pebbles. This evidently represents the usual indefinite belt between the two divisions.

The Maun flows in a deep valley cut into the Lower Mottled Sandstone between Bath Mill and Badger Hill, and over most of this distance the right bank of the river is a steep bluff showing crags of the red sandrock at frequent intervals. At Hallam's Grave a disused quarry shows Lower Mottled Sandstone with a three-inch band of red marl at its base, resting on Magnesian Limestones (*see* p. 14). Good sections are seen in the sandpit and the road-cutting near the bridge over the river below Rushpool Farm. Owing to the very slight dip of the Bunter the junction of the Lower Mottled Sandstone and Pebble Beds remains in the river-bluff for over a mile.

On the road to Market Warsop, a little south of the junction with the road from Rushpool Farm, there is a good section about 12 feet deep. North of the cross-roads there is a marked feature, about 60 feet high, which shows 15 feet of sandstone at the bottom. This feature probably marks the escarpment of the more massive beds of the Lower Mottled Sandstone. R. L. S.



BUNTER PEBBLE BEDS (PALE) ON LOWER MOTTLED SANDSTONE (DARK) IN QUARRY FOR MOULDING SAND AT ROCK HILL, MANSFIELD.

Bunter Pebble Beds.

In some parts of the country the Pebble Beds are almost wholly composed of pebbles, whence their name; but in Nottinghamshire their principal constituent is sand, among which pebbles are usually more or less thinly distributed, though sometimes clustered more abundantly in thin streaks and lenticles. The sand is coarser and cleaner than that of the Lower Mottled Sandstone, and is generally compact enough to stand with a vertical face in excavations. Nevertheless its coherence is always feeble, so that the sandrock is broken down by slight force into a loose sand. In spite of constant minor changes in structure and composition, the division maintains a general uniformity of character throughout the area. Consequently one exposure is very like another, and it will be unnecessary to enter into much detail in mentioning them.

The sandrock is not infrequently streaked at intervals with lenticles of red, or red and green, marl, varying in thickness from a mere film to a few inches, or occasionally to a few feet, and patches of this material appear to have been often broken up by contemporaneous erosion and distributed among the Pebble Beds in the form of rolled lumps and flakes.

The pebbles of the division are nearly always well-worn and smooth, and flattened oval shapes predominate. They range in size up to a diameter of 4 or 5 inches, but examples of the extreme size are rare. The majority are composed of quartzitic rocks, including quartzites, frequently dull-red or liver-coloured, vein quartz, siliceous breccia, jasper and chert, along with rarer pebbles of hard sandstone, felstone, greenstone, etc. The quartzitic sandstone pebbles occasionally yield fossils of Ordovician or Silurian age[1]. G. W. L.

DETAILS.

Mansfield district.—In the south-western district of the map the lower part of the Pebble Beds is exposed in road- and railway-cuttings and sandpits near Mansfield and in the river bluffs of the Maun. The sandpits have been referred to in the foregoing description of the Lower Mottled Sandstone. At the Mansfield Sand Co.'s pit the Pebble Beds are represented by 10 feet of gravelly sandrock resting on about 35 feet of coarse reddish sandrock with a few scattered pebbles and a lenticle of red marl about 3 feet thick (*see* Plate II). The other sandpits in the neighbourhood show similar sections. The growth of Mansfield eastwards has exposed sections between the roads to Farnsfield and Clipstone, some showing as much as 30 feet of Pebble Beds.

In the Maun Valley about 17 feet of sandrock is seen in the road past Hallam's Grave at 700 yards E. of the Maun. The lower portion of the Pebble Beds is well exposed above the pond at Woodhouse Warren, this and other sections in the neighbourhood showing an alternation of sandrock of the Lower Mottled and Pebble Bed types. The base of the Pebble Beds crosses the stream opposite Badger Hill; and in High Rocks Plantation the crags are of sandrock with pebbles, referable therefore to the upper division, though possessing the deeper red colour and finer grain usually characteristic of the Lower Mottled Sandstone. The rock is in fact a passage-bed between the two.

[1] Fossiliferous pebbles are recorded by Mr. A. T. Metcalfe from the Bunter at Farnsfield; *see* 'Geology of Nottinghamshire,' p. 17, in *White's Nottinghamshire*, Sheffield, 1893–4.

A point of some interest is the occurrence in the last-mentioned locality of small spherical bodies on the weathered surface of the sandrock, similar to those found in the drift near Farnsfield by Mr. B. Smith (p. 48). These pellets, which vary in size from mere granules to spheres of about a quarter-inch diameter, were first noticed 160 yards below the Weirs and were present for a space of 100 yards.

On the Mansfield-Southwell branch of the Midland Railway a long succession of cuttings shows excellent sections of coarse-grained reddish sandrock with pebbles and with frequent lumps of red marl which are usually arranged along planes of bedding. The rock is markedly cross-bedded with the dip towards the south-east A connexion between colour and texture is noticeable; the redder the rock the finer the grain. The deepest cutting is at Python Hill and is about 55 feet. Through the agency of the wind, the surface of these cuttings has been etched by the sand-blast and the upper part of the section has been worn away much more rapidly than the lower part.

Similar sections are revealed by the Chesterfield and Lincoln branch of the Great Central Railway. At Gorsethorpe near Clipstone, a sandpit about 55 feet deep, shows a fault in the Pebble Beds; on the upthrow side of the fault, at the bottom of the pit, 3 feet of fine-grained red sandrock resembling Lower Mottled Sandstone is seen, which, however, rests on pebbly sandrock. It is likely that the Lower Mottled Sandstone would be reached here at a slightly greater depth, but the amount of throw of the fault could not be determined. A small chert pebble found here contained the cast of a coral, probably *Heliolites*.

Thin bands of red, or red and green, marl are occasionally seen in sections of the Pebble Beds but are rarely traceable at the surface. At Brickkiln Hill, ¾ mile N. of Blidworth, however, a band of this kind has a definite outcrop which could be traced for over a mile and has been shown on the map. It must be several feet in thickness, but the only section is in the disused brickyard at Brickkiln End, where 5 feet of red clay is obscurely exposed.

Sections of the Bunter Pebble Beds in several deep wells and borings will be found in Appendix I., pp. 73-81. R. L. S.

Farnsfield district.—An old quarry-face in the inn-yard at Farnsfield, 150 yards NNW. of the church, exposes 2 feet of pebbly soil, resting upon 10-12 feet of soft red false-bedded sandstone with strings of pebbles and patches of red marl. The parish sandpit, 500 yards NW. of the church, furnished the following section:—

	Feet.
Sandy wash with pebbles	2
Fine-bedded sand with pebbles and lenticles of red marl ...	6-8
Cross-bedded soft red sandrock with strings of pebbles and balls of marl	14-16

The balls of marl are sometimes green, but more usually of a deep chocolate colour with a thin green skin, whilst the sandstone around them is white or yellow instead of the usual reddish tint. In these pits the cross-bedding dips at about 12° to the NE. or ENE.

A third pit, a few yards E. of the Farnsfield Windmill, shows 4 feet of pebbly drift overlying 12 feet of red cross-bedded sand, containing pebbles, scattered or in seams. Here the dip of the cross-bedding is between NW. and WNW. at about 15°.

About 220 yards N. of Ingars Holt a pit W. of the road shows a section about 12 feet deep, which includes 2 feet of pebbly conglomerate between beds of sandrock, cross-bedded, and containing seams of red and green marl in the upper part. The cross-bedded layers dip N.10°W. at an angle of 20°. The band of conglomerate is seen again in an old pit on the other side of the road, nearer the Holt, and gives rise to a feature traceable from the pits nearly to the Rufford Road, where it joins the scarp N. of Lockwell Hill.

The top of the Bunter was seen in a drainage channel, 550 yards W. of Bilsthorpe Church, at a point where the Waterstones Conglomerate is

exposed (p. 35), and at this place also it was very pebbly. The Rufford Road lies at the foot of a 50-ft. escarpment formed by the highest Bunter beds. Bare sandrock is exposed 340 yards SSW. of Red Bridge.

B. S.

Edwinstowe-Welbeck district.—The Pebble Beds form an irregular boundary with the Lower Mottled Sandstone from Clown Hill Plantation at the north edge of the map to the vicinity of Market Warsop from which they extend eastward over the forest lands.

Lenticles of red clay are occasionally present among the pebbly sands in this tract; they are usually so small that their presence can only be detected in open sections, but occasionally they attain larger dimensions and are apparent at the surface. One of these patches of marl occurs about $\frac{2}{3}$ mile SW. of Budby at the place marked CLAY on the map; and this patch is sufficiently large to have been worked for bricks.

Again, at $\frac{1}{3}$ mile SSE. and at 1 mile SE. of Budby there are indications of other small patches of clay, likewise marked on the map. A little red clay was also seen in a ditch $\frac{3}{4}$ mile ENE. of Gleadthorpe Grange.

In the forested park-lands there are few sections of the Pebble Beds. They are well exposed, however, in the road-cutting immediately north of Corunna Hill Plantation, which shows coarse red sand, with seams of pebbles from 2 to 6 inches thick, the individual pebbles ranging from fine gravel to 2 inches in size. There is another similar cutting immediately to the west of Corunna Hill Plantation, with banks which are 15 feet deep. Red sandrock is also exposed for some distance on the south-eastern bank of the Poulter at Carburton.

In a pit $\frac{1}{3}$-mile NE. of Gleadthorpe Grange gravel preponderates over sand, which in this area is exceptional. The gravel in this section is fairly compact, but the red sand is incohesive; it is possible that the deposit may belong to the Glacial series, but the absence of pebbles other than those common to the Bunter tells against this supposition.

J. B. H.

Ollerton district.—The Pebble Beds maintain their general uniformity of character throughout the Ollerton district in the eastern part of their outcrop, from Bothamsall, at the northern edge of the map, southward through the parks of Thoresby and Rufford to Bilsthorpe. They are well-exposed in the cuttings of the G. C. railway between Edwinstowe and the Keuper boundary east of Ollerton, consisting, as usual, of coarse-grained sandrock, sprinkled with pebbles and showing current-bedding with a prevalent slope to the east. There are also craggy exposures in the river-bluffs of the Maun N. of Whitewater Bridge, the crags in one place containing a shallow overhung recess, difficult of approach, traditionally known as 'Robin Hood's Cave' (a not unlikely hiding-place for an outlaw). Other sections may be seen in road-cuttings at Bothamsall and Ollerton, and in small sandpits, marked on the map, at Walesby, Kirton, Thoresby Park and S. of Rufford Park.

The presence of a belt of more gravelly composition toward the upper part of the formation appears to be indicated by a long irregular strip of moundy stony ground which runs along the E. side of Thoresby Park and, farther south, on the W. side of the Rainworth valley. But it is possible that this feature may be due mainly to the relics of drift-gravels spread out by the Late-glacial floods which initiated the courses of the present streams (p. 49-50). Pebbles are also concentrated at the surface of the Bunter in exposed situations through the blowing away of the sand, when the land is put under cultivation. Good examples of this wind-drift of sand were noticed west of Primrose Hill near Rufford, and in the strip of very light land between Boughton Brake and Warren Farm near Haughton. Toward the Keuper boundary the soil becomes more loamy and of better quality, apparently due partly to the residue of the clayey Keuper which once covered it, and partly to its moister condition from the shallower level of the ground-water. Its quality has no doubt also been aided artificially in the past by 'marling,' as the numerous old marl-pits along the neighbouring Keuper escarpment show how extensively this process has been practised, though now almost extinct.

The presence of thin bands of marl interstratified with the Pebble Beds is occasionally indicated by the sandy soil becoming more loamy, but in most cases these are evidently short lenticles. In a few instances, however, they are sufficiently thick and persistent to possess an identifiable outcrop. Thus, on the W. side of Bilhaugh plantation, about a mile SE. of Budby, in the neighbourhood of other clayey patches previously mentioned (p. 23), clay has been dug in some small pits, now obscured, and the neighbouring ground is wet and spongy; also in three or four places in Thoresby Park N. of the Meden valley, and in the S. part of Clumber Park there are ponds showing red clay in their sides and bottoms, but so much has been done artificially in this tract, that the clay may have been brought there for puddling. The clay is undoubtedly in place in Freeboard Lane at the N. margin of the map, between the two parks, and was formerly dug here on the Clumber side of the border, the neighbouring plantation being still known as Claypit Wood. The pit is still recognizable but the section is now overgrown, though some red clay can be seen in the bank. A small glaciated boulder of Magnesian Limestone (8 inches in longest diameter) was noticed here, which raises the possibility that the clay in this case may be Glacial and not Bunter. G. W. L.

CHAPTER V.

TRIAS (*continued*):—KEUPER.

General Account.

The Keuper formation rests upon a slightly uneven surface of the Bunter, which dips, as proved by borings (*see* Appendix I. pp. 73-81), at an average of 105 feet per mile, *i.e.*, at about 1°, in a direction slightly south of east. The dip of the Keuper conforms closely with the average dip of the Bunter surface, but varies from about ½° on the western side of the outcrop, to about 2° on the east.

The formation in this district is somewhat thicker than in South Nottinghamshire, where at Owthorpe[1] (Sheet 142 N.S.) the total thickness proved was 749 feet, increasing to about 800 feet north of Nottingham[2]. Calculating from data yielded by borings at South Scarle,[3] Newark[4] and other places, the full thickness of the Keuper at the eastern side of the present area is about 900 feet.

The base of the Keuper can be readily traced owing to the sharp distinction between its green clayey basement beds and the underlying sandy Bunter. It is also marked by a shallow depression of the country, often containing springs and marshy ground where the water-table in the Bunter reaches the surface. The actual junction was seen at several points between Bilsthorpe and Bothamsall. In most cases a few inches of grey or green calcareous conglomeratic sandstone underlay the grey-green clays, and rested directly upon cross-bedded Bunter sandrock. This impersistent conglomerate forms the lowest bed of the Keuper, and indications of its presence were found here and there in the soil where no clear section of the junction was exposed; it has likewise been met with occasionally in borings. It suggests some slight unconformity between the formations, a suggestion that is supported by minor differences of strike between the Bunter features and those of the Keuper, noticeable in a few places (*e.g.*, near Farnsfield).

Waterstones.

Of the two main divisions into which the Keuper is separable—the Waterstones and the Keuper Marl—the former presents the most variation both in thickness and composition. The difference between the divisions, however, in the neighbourhood of their junctions is so slight that some of

[1] 'Geology of the Melton Mowbray District,' *Mem. Geol. Surv.*, 1909, p. 104.
[2] 'Geology of the Country around Nottingham,' *Mem. Geol. Surv.*, 1910, p. 36.
[3] 'Geology of the Country around Lincoln,' *Mem. Geol. Surv.*, 1888, p. 194.
[4] 'Geology of the Country between Newark and Nottingham,' *Mem. Geol. Surv.*, 1908, p. 105.

the variation in the thickness assigned in different places to the Waterstones may be due to the dividing line having been taken locally at different horizons; but part of the variation is certainly due to the actual thickening and thinning of the beds, and possibly also to the slightly irregular surface of the underlying Bunter. The lithological difference between the upper part of the Waterstones and the lower part of the Marls decreases as the beds are followed in a northerly and easterly direction, so that north of Wellow the main criterion in mapping the division has been the position of the lowest skerry-band in the Marls. An estimated average of about 230 feet may be assigned to the Waterstones of this area, with a range between limits of 180 and 250 feet, the latter figure being reached at the Silk Mill boring in the Greet Valley. In the record of the Scarle[1] boring 205½ feet is allotted to them.

The Green Beds.—The greenish clayey basement beds of the Keuper were first noticed by W. T. Aveline who, in 1861, drew attention[2] to the "alternations of soft blue sandstone and blue clays" at the base of the Waterstones in this part of the county. These beds set in near Oxton (in Sheet 126, a mile or two south of the present map) and continue as a well-marked division throughout our district, leaving the map at Bothamsall. They have also been identified in several borings east of their outcrop, and afford a useful indication of the proximity of the Bunter. They are 20 to 25 feet thick, and consist of micaceous ripple-marked pale clays, shales and sandy shale, of grey-green, grey-blue, or sometimes reddish tints, with occasional streaks of gritty sand, calcareous nodules in places, and obscure fragments of carbonised organic matter (probably plants).

As the beds are readily separable in this district from the Waterstones of normal type, the boundaries have been shown on the map by lines within which CLAY is engraved, but the same colouring is used as for the rest of the Waterstones.

Where the clays are dug for pottery-making at Farnsfield, their base is not reached, the lowermost beds being unsuitable for the purpose. The section appears to disprove the presence of the inlier of Bunter in this neighbourhood inserted upon the old map.

Normal Waterstones.—The Waterstones above the Green Beds consist of irregular intercalations of marl and shale with soft red, brownish-red, and whitish porous sandstones, and more compact pale dolomitic sandstones. Of these, red marls and shales make up the greater bulk, but grey-blue marls and shales are also common, especially near the top of the series. The finer sandstones are sometimes strongly ripple-marked, and contain nests of white mica in the hollows between the ridges. They also enclose small flattened pellets of marl, and, very rarely, a few small pebbles. The dolomitic sandstones occasionally show

[1] 'Geology of the Country around Lincoln,' *Mem. Geol. Surv.*, 1888, p. 194.
[2] 'Geology of the Country around Nottingham,' *Mem. Geol. Surv.*, 1861, p. 18.

crumpled structures similar to those in the skerry-bands of the Marls presently to be described. No fossils have been found in the Waterstones of this area, though a fish spine, or bone, and a few markings that may be tracks of annelids were obtained from them in Westhorpe Dumble near Southwell (Sheet 126), just south of the present limits. Certain beds exposed in a road-cutting about ½ mile west of Markham Clinton look promising and might repay a prolonged search. Salt pseudomorphs, and gypsum in fibrous plates or small balls 2-3 inches in length, occur at intervals throughout the series, but less commonly than in the overlying Marls.

The thicker bands of sandstone occur mainly, but not wholly, in the lower part of the series. Near Eakring and Wellow, and again near Bevercotes, the principal sandstones form two distinct features, the higher projecting as a shelf from below the Marls, while the lower rises above the gently sloping outcrop of the Green Beds.

The chief criterion for distinguishing between the Waterstones and the Marls is the absence of red sandstones in the latter. The adopted line of division usually lies high up in the Keuper escarpment which, although almost always capped by the Marls, is for the greater part of its course mainly composed of Waterstones. The highest beds of the series consist of flaggy thin sandstones, dolomites, shales and marls of variegated hues (blue, brown, chocolate, green, grey, purple and red). The westward protrusion of the Keuper boundary at Haughton and again in the southern part of Rufford Park is probably due to a slight rolling of the strata at right angles to the average strike. On the original 'Old Series' map it was assigned in the first-mentioned case to the influence of a fault, but the persistence of the Green Beds along the junction is opposed to this interpretation, though there may possibly be a small fault concealed in the Meden-Maun Valley between Bothamsall and Haughton, as the red sandy beds of the Waterstones are lower on the north slope of the valley than we should expect. The smaller protrusion south of Crifton Lodge may be due to an original hollow in the Bunter surface, or to a small fault for which there is no definite evidence.

It should be understood that the term 'Waterstones' in the technical sense was not originally applied to the division because of its water-bearing properties, but from the peculiar 'watered' structure occasionally noticeable on the surfaces of the beds[1]. The sandstones of the series do, in fact, frequently yield a limited supply of water, and the term is thus applicable in the more literal sense also, and is indeed frequently used in the Keuper districts with this meaning by well-sinkers and others, who, however, are apt to apply it indiscriminately to any bed in the Keuper formation that happens to yield water.

[1] *See* H. B. Woodward, 'Geology of England and Wales,' 2nd edit., 1887, p. 227.

Keuper Marl.

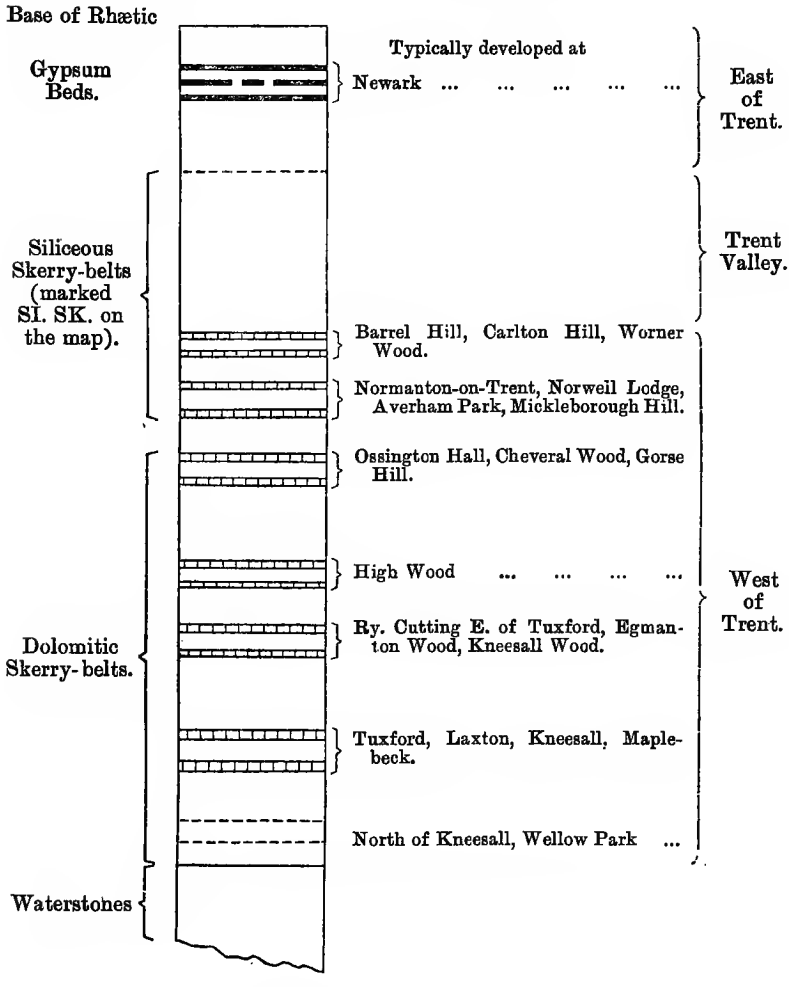
Including the tracts along the Trent where they are overlain by superficial deposits, the Keuper Marls cover an area of over 100 square miles in the map. They average about 670 feet in thickness and consist principally of red marl with greenish streaks and blotches, intercalated at intervals with sandy bands known as 'skerries' which frequently consist to a great extent of dolomite. Unlike the majority of the red sandstones of the lower division these skerries are nearly always pale-grey or greenish-grey in colour, though the thinnest layers are occasionally stained pink. The minor surface-relief of the Marl country is directly due to individual skerries, or groups of associated skerries (which with their intercalated shaly marl may be designated 'skerry-belts'), for in the absence of drift the Marls weather in such a way that practically every resistant bed makes a feature, even though the bed itself be invisible at the surface. In exceptional cases a band of hard blocky marl gives rise to a feature, but most of these surface-shapes are due to the skerry-belts. These belts, composed of alternations of micaceous sandstone with variegated shale and marl, are usually about 6 feet in thickness. They are occasionally veined with gypsum and are remarkably persistent as a whole, though variable in the development of any particular bed.

Skerry-belts.—Where the Keuper Marl plateau is least dissected, the successive skerry-belts do not often form prominent features, but come on gradually, first the lower layers, and then the higher ones, with a comparatively slight change in the surface slope. But where the plateau is well dissected, and especially where strike-streams have trenched the upland, the beds forming the belt stand out conspicuously. The characteristic result is the production either of long even-crested ridges, or of plateaux, from which gently-terraced slopes descend to the valleys. The dissected plateaux near Tuxford and Laxton, Mickleborough Hill, 2 miles west of Kelham, and the hill south of Bevercotes may be cited as good examples of the characteristic form.

With regard to the distribution of the skerries, as distinct from skerry-belts. Aveline rightly remarked[1] that over the whole formation there is not 20 feet of marl without one or two beds of this sandstone, either thick or thin, although the chief beds are found towards the bottom of the marly series. Under these circumstances it is, of course, not possible to trace every individual band, but in mapping the ground upon the 6-inch scale, all the more important belts were traced. On the 1-inch map, however, only a selection of these belts can be shown. In cases where two belts occur close together (Fig. 3, p. 29), only one can be represented on the smaller scale; and it frequently happens that, in places, the belt shown on the map is of the lesser importance as a feature-maker, although it is the chief of the two elsewhere. The conditions under which this may occur are shown in Fig. 4.

[1] 'Geology of the Country around Nottingham,' *Mem. Geol. Surv.*, 1861, p. 19.

FIG. 3.—DIAGRAM SHOWING THE SEQUENCE OF THE PRINCIPAL SKERRY-BELTS, ETC., IN THE KEUPER MARL. (*B. Smith.*)

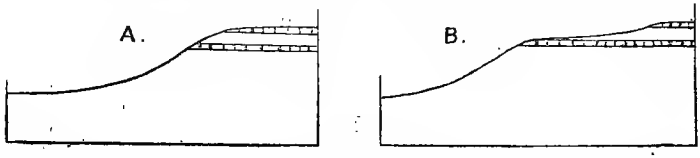


The contiguous skerry-belts bracketed on the right are shown by a single line on the one-inch map.

The skerry-belts represented by broken lines are not shown on the map.

At A the upper of the two belts forms the brow of the scarp, but at B it has been worn back so that the scarp is dominated by the lower belt.

FIG. 4.—BROW OF FEATURE WHEN (A) DOMINATED BY AN UPPER SKERRY-BELT, AND (B) BY A LOWER BELT. (*B. Smith.*)



The individual sandstones of the skerry-belts vary in thickness from an exceptional thickness of 3 feet to less than ½ inch. The intercalated sandy shales, when unweathered, are frequently so hard that they are entered as 'stone' in the well-sinkers' records, so that as much as 20 feet of hard stone is frequently reported. At the surface, however, such 'stone' rapidly disintegrates and only the ribs of sandstone remain. The thickest beds of sandstone noted during the survey were exposed near Brecks Farm and Hagley's Dumble west of Maplebeck, and at Tuxford. Much stone for building, etc., has been raised from these or similar beds near Hockerton, Maplebeck, Kneesall, Laxton, Egmanton, Tuxford and Markham. The villages are in some cases built into, or founded upon, the belts of rock, and almost every church upon the outcrop was originally built of the local stone. It was also employed in the construction of the Old Bishop's Palace at Southwell and of Bishop Alexander's Castle and the Trent Bridge at Newark.

Pseudomorphs after salt crystals are of frequent occurrence in the shales and sandstones; in the latter they are usually found upon the under surfaces[1] of the stone, although sometimes embedded within its substance.

In their stratigraphical distribution the skerry bands may be classed by differences in composition into two separate types, which occur in ascending order as follows (*see* Fig. 3, p. 29):—

1. Pale fine-grained sandstones with much dolomite.
2. (*a*) Pale flaggy siliceous sandstones with less dolomite.
   (*b*) Coarser sandstones with rounded grains, mostly siliceous.

The skerry-belts containing sandstones of Class 2 are indicated on the map by the symbol SI. SK.

1. In the first group are the skerries which form the main stone-horizon near the base of the Keuper Marl and range upward to 360-370 feet above the base. They give rise to most of the characteristic plateau features. They are frequently ripple-marked, and sometimes show a peculiar contorted arrangement of the layers, whereby lumps of softer laminated stone lie rolled up and embedded in the harder portions, and tend to weather into cavities.

[1] *See also* J. F. Blake in Article on Geology, *Vict. Count. Hist. of Notts.*, p. 27.

Microscopic examination shows that these sandstones consist of grains of quartz and rhombs of dolomite (showing signs of attrition) in about equal proportions; a little calcite may also be present. In the ripple-marked and contorted bands, the laminæ show original variability in composition, alternate layers being richer or poorer in one of the constituents. The ripple-marks are undoubtedly due to current action and it is supposed that the contortions may have also been formed by currents[1].

2. (*a*) The lower sandstones of the second group set in above those last described, though a few thin layers of the former type are also present. The skerries of this group are mostly thinner and less persistent than those of the lower series. They form prominent features extending from Mickleborough Hill and Averham Park in the south, to Normanton-upon-Trent in the north. They are probably equivalent to the skerries of Scarrington and Hawkesworth[2], south of the Trent Valley, and, like them, have generally a siliceous banded appearance, and weather out in the soil into rough slaggy-looking fragments with a brown or blue-black stain—strikingly different from the paler and cleaner stone of the lower skerries. They contain a much higher proportion of quartz-sand than the lower group, and the cementing material is partly siliceous. The quartz grains are coarser and there are also some alkali felspars. Angular cavities in the rock may represent calcitic mud.

2. (*b*) Near North and South Clifton the skerries are characterised by their highly siliceous character and the coarseness of their sand-grains which comprise 95 per cent. of the rock and occur in two sizes, the larger often beautifully rounded, the smaller angular and packed in the interstices between the larger grains. Felspars and rolled fragments of dolomitic sandstone also occur amongst the larger grains. These rock-bands are very thin and recur much less frequently than those of the lower groups. They are the most characteristic sandstones in the higher parts of the Marl to the east of the Trent Valley, and may possibly represent the horizon of the Tythby[3] sandstone of the Vale of Belvoir, situated about 120 feet below the Rhætic Beds.

Above the range of this group of skerries thin sandy bands of indefinite type occur from time to time in association with the gypsum beds, but on the whole this part of the Keuper Marl is comparatively free from skerry.

Marl-belts.—Just as there are differences in the skerries, so also the marls themselves show differences of composition in the vertical sequence, occurring in belts which may have as great horizontal extent as the skerries; but it is noteworthy that there is sometimes a lateral variation also—for example in the clays

[1] *See* B. Smith, 'The Upper Keuper Sandstones of E. Nottinghamshire,' *Geol. Mag.*, 1910, p. 306. For the effects of currents on sand, *see* Sorby, 'On the Application of Quantitative Methods to the Study of the Structure and History of Rocks,' *Quart. Journ. Geol. Soc.*, vol. lxiv., 1908, pp. 180–185.

[2] 'Geology of the Country between Newark and Nottingham,' *Mem. Geol. Surv.*, 1908, pp. 41 and 50.

[3] *Ibid.*, p. 50.

of Kneesall brickyard. These differences in composition are brought out by the character of the soils on the outcrop.

The marls are practically indurated silts containing a high percentage of silica along with small isolated rhombs of dolomite; the coarser silts, with the sandy dolomitic shales and marls associated with them, break down to a somewhat sandy soil, while the finer silts behave as tough clays. Above a skerry band it is common to find sandy shales, which pass upward gradually through sandy marl into fine homogeneous marl. Where the skerry-belts are near the surface, as on many of the plateaux, the soil is usually a stiff loam containing fragments of sandstone.

A good example of the horizontal extent of a particular bed of marl is afforded by the belt of brick-clay beneath the main skerry belts between East Markham and Laxton, and this bed is probably continuous as far south as Maplebeck. Again, a broad belt of very stiff red clay runs from Darlton Field in the north, past Egmanton Common Farm, Broadwaters Farm, and Caunton, to the plateau east of the Car Dike in the south.

Gypsum.—The upper 100 feet or more of the Keuper Marl is on the whole of the fine-grained type, and contains near Newark workable beds of gypsum, which occur mainly near the top of the formation, terminating about 30 feet below the Rhætic Beds. Details of the extensive workings of Messrs. Cafferata & Co. (*see* Plate IV., p. 67), which just enter the area near the south-east corner of the map, have been given in a recent memoir[1]. The gypsum at this horizon appears to be mainly of original deposition, but elsewhere in our district it occurs principally as fibrous crystallised veins formed subsequently to the deposition of the marls. These veins range up to 5 or 6 inches in diameter; the larger are nearly horizontal, others are inclined, or vertical, and form interlaced stringers and plates, which have often destroyed the bedding of the marls. Gypsum likewise occurs occasionally as a cement to broken-up red or green marl. Here and there the fibrous gypsum gives place to selenite crystals, sometimes arranged at right angles to the fibrosity, on the top or bottom edge of the plate, or even in the centre. In inclined veins there is often a local deflection of the fibres along the central line of the vein, suggesting that the fibres grew from the outer walls of a fissure and joined up in the centre. Pieces of marl are sometimes enclosed between the two halves of a vein.

Fibrous gypsum occurs in quantity about the horizon of the main skerries of the first group north of Kneesall, rendering the well-waters extremely hard. It is also plentiful in the marls forming the river-bluff north-west of North Clifton. Massive gypsum has been reported to occur at Kneesall, and W. H. Dalton records[2] gypsum "in the usual form of thick lenticular masses, but also as horizontal and oblique veins" in the sandstone horizon near the bottom of the Marls at Clarborough, about 6 miles north of East Markham.

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[1] 'Geology of the Country between Newark and Nottingham,' *Mem. Geol. Surv.*, 1908, p. 53.

[2] 'Geology of the Country around Lincoln,' *Mem. Geol. Surv.*, 1888, p. 8.

Tea-green Marl.—The red colour prevalent through the greater part of the Keuper Marl is lost in the uppermost beds which are of a pale greyish-green tint and are therefore known as the Tea-green Marl. Thus the top of the Keuper is in some respects similar to its base, inasmuch as grey-green clayey beds occur in both positions. Except in colour, however, the Tea-green Marl differs hardly at all from the red marls. It is 18 feet thick at Beacon Hill, Newark, where its junction with the Rhætic is exposed, but no clear sections were seen in the area mapped.

Structure.

Detailed mapping of the outcrops of the skerries has shown that there are slight undulations in the Keuper Marl at right angles to the general strike of the beds. Thus, a feeble anticline appears to trend through Muskham Wood and Eakring in the southern part of the district, while the Goosemoor Dike, south-west of Tuxford, is apparently excavated along a shallow syncline. The dip on the western spurs of the Keuper sometimes approaches horizontality, and in one or two places a slight reversal of direction was suspected. The faults that were detected were all small, the most important being the two faults running in a north-westerly direction from near Barrel Hill, Sutton-upon-Trent, to near Egmanton. The fault shown on the old map as running past Nickerbush Plantation and Haughton Decoy has been discarded for the reasons stated on p. 27.

Conclusions.

Reviewing the whole sequence of the formation and its extension in neighbouring areas, we may deduce the following conclusions with respect to the climate and physical conditions under which the Keuper of this area was accumulated[1].

Both Waterstones and Keuper Marl appear to have been deposited in a wide but shallow inland sea or salt lake lying near an upland where arid continental conditions prevailed. From this neighbouring land much débris was swept down by occasional floods which also temporarily increased the extent and depth of the sea. Isostatic conditions seem to have prevailed throughout the basin, for the skerries, indicative of shallow water and current action, never entirely ceased to be formed.

One shore-line of the sea or lake probably lay to the west or north-west at the beginning of Keuper times, as the Waterstones at their outcrop in Nottinghamshire bear evidence of shore and lagoon conditions by the presence of a basal conglomerate, the abundance of sandstone and sandy shales, the frequency of salt-pseudomorphs, ripple-marks and sun-cracks, and the mode of occurrence of their scanty fossils[2]. Farther eastward, on the other hand, the Waterstones, when penetrated in borings, as at

[1] *See* B. Smith, 'The Upper Keuper Sandstones of E. Nottinghamshire,' *Geol. Mag.*, 1910, pp. 308–311.

[2] 'Geology of the Country around Nottingham,' *Mem. Geol. Surv.*, 1910, pp. 37, 38.

Rampton (east of Retford) and at Lincoln, are hardly distinguishable in composition from the Keuper Marl which appears to have been an off-shore deposit.

The dolomite rhombs in the skerries, and in some of the Waterstones, may have been deposited directly from solution, as suggested by Dr. C. G. Cullis[1] for those in the Marl; yet in most cases the rhombs appear to have suffered attrition, and have probably been drifted for some distance, along with the quartz-grains and other detrital fragments. Most of the quartz and felspar may have been derived from Carboniferous sandstones and grits; and from the same formation may have come the material of the finer calcareous and dolomitic shales and marls[2]. As regards the marls, Sorby[3] has shown that such homogeneous clays may be deposited either by gentle and uniform currents drifting fine sediment to spots where there is hardly any current at all, or to quick deposit of cohered mud from tranquil waters. The passage from sandy shales to fine marls, mentioned above, favours the first of these alternatives. In addition windborne sand and dust may have added largely to the sediments.

The irregular recurrence and wide extension of the skerry-belts suggests that they may represent occasions when the area was temporarily invaded by more powerful currents due to flood-waters, each skerry-band marking a single flood, and the succession of several bands in a skerry-belt marking a period of several wet seasons, following periods of greater drought. B. S.

DETAILS.—WATERSTONES.

Conglomerate and Green Beds.—The Green Beds are first noticeable near Combs Farm and Combs Wood, at the foot of the sandstone escarpment, where they give rise to a grey loamy soil; and they become prominent near Farnsfield, where the surface-relief is such that their outcrop extends nearly to Edingley beneath the gravel of the moor. Green clays are dug at the Old Pottery SE. of the Waterworks, to be made up in the village. At the NE. end of the excavation 2 feet of stony loam and sand overlies 4-5 feet of greenish loamy pottery clay, beneath which there is 1 foot of undesirable sandy shale resting upon a hard green layer several inches thick, but without pebbles. Occasional stones and thin red marly streaks are found in the clays. The shaly beds contain some small obscure fragments of plants showing cell-structures under the microscope.

Patches of the green clays and loams are embedded in the overlying Edingley Moor gravel, and since there are also patches of red marl caught up, it is probable that some red clays are developed here similar to those at Bilsthorpe, to be mentioned later. The outcrop W. of the gravel is partly obscured by rainwash from the Bunter and by relics of the gravelly loam which formerly covered it. In Lower Hexgreave Park the thin Waterstones Conglomerate forms a very slight feature above the Bunter sandstone. Green beds underlie the normal Waterstones of Upper Hexgreave, and can be easily traced by their greenish-blue colour when freshly exposed, and yellowish brown tint when weathered.

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[1] 'On a Peculiarity in the Mineralogical Constitution of the Keuper Marl,' *Rep. Brit. Assoc.* for 1907, pp. 506, 507.

[2] For analyses, *see* 'Geology of the Melton Mowbray District,' 1908, p. 100, or 'Geology of the Country around Nottingham,' 1910, p. 39.

[3] 'On the Application of Quantitative Methods to the Study &c. of Rocks,' *Quart. Journ. Geol. Soc.*, vol. lxiv., 1908, p. 196.

The Greet rises from numerous springs in the Green Beds about half a mile ESE. of Lower Hexgreave, and where the flood-gravels are stripped away at least twenty-four vigorous springs were counted in as many acres. Kirklington Hall is supplied by artesian water from these beds near Belle Eau Park. The 10-ft. well with a 10-ft. borehole in the bottom may reach the Bunter sandstone.

In an artificial cutting, crossed by a small bridge about 550 yards W. of Bilsthorpe Church, the Green Beds are well exposed, above an 18-inch conglomerate which dips off the Pebble Beds at about 2° to south-east. The conglomerate is a greenish felspathic sandstone with a calcareous cement, enclosing pebbles of quartzite, white vein-quartz and chert, up to 2 inches in size. The cutting also crosses the overlying green micaceous shales, marls, and thin sandstones (with occasional red marls), and then enters some red marls and shales with green layers W. of Bilsthorpe Moor. B. S.

Though no actual exposure was observed, the junction of the Keuper clays with the sandy Bunter is sharply defined S. of Ollerton, in the fields N. of Rufford Hills Farm, and along the NE. corner of Rufford Park; and traces of the basal conglomerate were noted where the junction crosses the side valley (Gallow Hole Dike) SE. of the old kennels in the park.

The Green Beds are occasionally dug in a small brickyard between Wellow and Rufford Hills Farm. In 1907 the section here showed 1½ ft. of disturbed red and mottled clay passing down into greenish-grey clay of which about 3 feet was seen; a few stones in the top clay indicated the former presence of Glacial drift, and several boulders, mostly of Carboniferous Sandstone, were noticed in the spoil, including one of whitish sandstone measuring 2½ feet by 2 feet by 1 foot.

The clays were seen still better in the recently cleaned gutter of Boughton Dike 400 yards NE. of its culvert under the railway; this section showed up to 6 feet of grey micaceous silty shales, non-calcareous, containing flaky brown patches like ill-preserved fish-scales or bits of plants. Almost everywhere along the outcrop of these beds there are minor exposures in ponds, gutters, &c., in which the shaly material is weathered to a very tenacious pale clay.

Going northward, the actual junction is obscurely exposed in a sheep-wash near Boughton, where the stream (Boughton Dike) is crossed by the high road leading east from the village. The green clays are again visible along the same stream a mile lower down, where it is crossed by the footpath between the villages of Kirton and Walesby; and about 200 yards farther N. they are seen to be underlain by a band of hard calcareous conglomerate 3 or 4 inches thick, which is also exposed in the bank of the stream 50 yards farther N., with soft Bunter sandrock below.

The junction is next seen at Haughton, on the south side of the River Maun, in a small overgrown pit 350 yards W. of the mill, but is not well exposed. The green clays form the bed of the river from near this point to the mill. Traces of the conglomeratic basement bed were also noticed near here, and in a ploughed field between Crow Park and Haughton Decoy.

At Bothamsall, on the northern side of the Maun-Meden valley, the same Green Beds are worked in a small brickyard N. of the village; and the neighbouring road-cutting, just outside our map, shows a foot or two of flaggy calcareous grey sandstone, beneath the green clays, resting on cross-bedded Bunter sandrock of the usual type, which is further revealed to a depth of 20 feet in an adjacent sandpit. The brickyard section shows about 6 feet of grey sandy clay containing an interrupted streak of coarse sand about an inch thick; large calcareous concretions are dug from the lower part of the section, while at the top there are a few irregular pockets of red pebbly drift. A well in the brickyard is stated to have passed through 6 feet of grey clay and 8 feet of grey and red clay and skerry, and then to have entered the Bunter sandrock. G. W. L.

Waterstones above the Green Beds.—The lower and main sandstone horizon in the Waterstones above the clay-belt forms a bold scarp between Combs Wood and Riddings Hill Farm, about 100 feet above the Green Beds, and is continued to Edingley Hill, from which a well-marked dip-slope descends to Littledale, where a borehole near the alluvium reached the Bunter at 118 feet. NE. of the latter place the beck exposes thin greenish

and red ripple-marked flaggy sandstones with red and green marls; but the best section of the sandstones is in the Edingley Hill road-cutting. The higher parts consist of thick-bedded red sandstones with shaly partings, dipping locally at 3° and 5° to the S. and SE.; the lower parts contain more marl and shale. The sandstone feature continues to Goldhill and the hill SE. of the station. Copious springs issuing from the escarpment between Old Hall and Edingley Hill enter the beck at Edingley and add their quota to the Greet, which is also fed by numerous springs near Kirklington. Soft sandstones are exposed in the road-cutting north of Kirklington Mill, dipping to NNE.

The outcrop is covered by a clayey loam containing fragments of the soft red sandstones and shales and a few Bunter pebbles. At the roadside N. of New Hall, and behind the ponds W. of Kirklington Mill, the hedges have held up a thick deposit of rainwash, often 8 feet or more in thickness.

In the beck S. of Whip Ridding Farm an almost continuous section of sandstones, shales and marls is laid bare upon the E. side of the road, the harder flags forming a series of small waterfalls. Similar, but better, sections occur in a branching dumble, about 20 feet deep, some 300 yards E. of Fox Holes. In the lane below Bilsthorpe Church there are 4-5 feet of the lower ripple-marked sandstones above a local development of red marls.

B. S.

The belts of sandstone in the lower half of the division often individually form features, giving rise to a terraced escarpment which is particularly evident between Eakring and Wellow. Being exposed more frequently than the interstratified marls, their relative proportion is liable to be overestimated; the Waterstones in this district include more marl than sandstone. The belts do not appear to be strictly continuous, but vary in their development from place to place, resembling in this respect the skerries of the Keuper Marl. The stone was formerly quarried locally for building, but is now rarely used, and most of the sections are obliterated. The best exposures of the lowest belt at present are in the stream-gully at Wellow village; in a road-cutting and an old quarry close to Kirton Church; in road-cuttings and in the bank of the beck at Bevercotes; and in excavations around some of the buildings in Bothamsall village. A higher sandstone forms the shelf on which Eakring stands, and is sparingly exposed in the roadsides and small pits around the village.

G. W. L.

NE. of Eakring the higher sandstones form a platform dipping to the east and dissected by the head-waters of the Caunton Beck. Near Leyfields they form a shelf (at about the 200-ft. O. D. contour) in which there are several old pits. Well shafts at Leyfields have penetrated the Waterstones to some depth.

Near Grimston Hill the upper sandstones form an extremely gentle and slightly terraced dip-slope emerging from beneath a few feet of variegated strata. The sandstone feature near the top of the Waterstones is, in the neighbourhood of Ompton, pitted with old and deep excavations, probably dug for marling purposes. About 60 yards S. of the Ompton-Kneesall Road, N. of Lound Farm, there is a poorly-exposed section in an old pit situated below the Keuper Marl escarpment. Thin red or pink micaceous and ripple-marked sandstones (the long axes of the ripples usually directed a little W. of N.) lie below variegated banded clays and shales, with fragments of soft sandstone with biscuit-like break. Above these are red and green marls and shales, some of the latter having the characteristic 'watered' appearance. In Ompton village, wells 12-18 feet deep are sunk in sandstones, the water entering from the west. Ripple-marked micaceous sandstones, up to 4 inches in thickness, are also exposed in a pond section a few yards N. of the main road. In this case the long axes of the ripples point slightly E. of N.

The upper sandstones form a series of small features in the valley south of Prior's Park and give rise to a broad terrace and escarpment NE. of Farleys Wood. At a point about 250 yards from the Bevercotes-Milton road, and half a mile NNE. of Farleys House, a brook has cut a 12 ft. section in alternations of flaggy red sandstone and blocky sandy marl and shale. The field-track from Markham Clinton to Bevercotes crosses the scarp in a cutting, which at its deepest exposes about 10 feet of red and

grey micaceous marls and shales with thin layers of ripple-marked red and grey (probably dolomitic) sandstone. Most of the ripple-marks have their long axes arranged north and south, but others cross these nearly at right angles. Some of the coarse sandstones contained flattened elliptical and angular pellets of marl, frequently olive-green in the grey beds and chocolate in the reddish beds. One pale sandstone contained rolled pebbles of a previous sandstone, and another bore salt pseudomorphs. These beds might repay a diligent search for fossils.

Several features near Milton are due to hard beds, which are occasionally grey, like the skerries above. The village wells at the foot of the scarp hold water at shallow depth. Sibthorpe Place stands upon the sandstone feature, here breached by a small tributary of the Maun. Sandstones are reported in the bed of this stream W. of the inn. B. S.

The upper marly and shaly beds of the Waterstones, already mentioned as being generally very variable in texture and tint, are revealed in numerous shallow sections along roadsides and in stream gullies. In the greater part of the district they are not well exposed; and the best section within the map, in the railway cutting NE. of Boughton Station, is now sloped and grass-grown. They are seen, however, in the lane leading W. from Eakring to Rufford Stud Farm, which exhibits a succession of sandy micaceous shales, marly clays and thin sandstones for a thickness of 30-40 feet; a similar succession can be made out, though not so clearly, in the steep road up the hill (Cocking Hill) between Boughton Station and Laxton Common; and more clearly, in the road-cutting alongside Nickerbush Plantation ESE. of Walesby. There are also many small exposures in the stream-gully or dumble in Bevercotes Park. G. W. L.

In the inlier between Laxton and Kneesall, variegated beds, dipping eastward, are visible in the stream-bank E. of the road from Kneesall to Laxton Mill Field, and a belt of sandstones is exposed beneath them about 120 yards W. of the road. From this point the sandstones are traceable by feature all round the inlier to within about 150 yards of its western extremity, where they are again visible in a small dumble.

The inliers of the higher Waterstones W. of Egmanton and Tuxford are inserted partly upon the evidence of their position beneath the lowest skerry and partly upon their composition.

Variegated beds rest upon a floor of flags and shales in the dumble at the southern extremity of Kirton Wood, and other sections occur up to the point where the alluvium commences. At this point, and 90 yards SW. of it, there are two anticlines (axes NW. and SE.) in thin flags, sandstones and shales. In the second case the amplitude of the anticline is about 6 feet, and the base 10 feet in length. The beds are slightly overfolded, the axial plane being inclined to the north-east. Since the trend of the anticlines is the same as that of the faults in this district, they are probably due to the same cause.

About half a mile further ENE., shales, flags and sandstones dip at a low angle down-stream, in which direction they are followed by the variegated beds. In the hollow W. of Tuxford variegated beds are exposed in the brook near the western termination of the mapped alluvium.

In the valley of the Goosemoor Dike the variegated beds form a small feature beneath the lowest skerry platform in the Keuper Marl, upon each side of the railway line; and south of Prior's Park the underlying sandstones give rise to terraces upon the hillside. An overgrown excavation near the line, about 500 yards WNW. of Winson Hill, is probably the site of an old brickyard.

In Markham Clinton the Waterstones are exposed in a cutting and ditch-section extending for about 100 yards SSW. of the old church; some of the sandstones are grey and dolomitic. The junction with the marls is vaguely defined by a line of springs.

Heavy rainwash covers the lower slopes in all the valleys. B. S.

DETAILS (*continued*).—KEUPER MARL.

West of the Greet.—A cutting at the road bend, ¾ mile SW. of Edingley, exposes 12 feet of marls with two beds of greenish-grey sandstone: skerry

is also very close to the surface at New Hall, where fragments are common in the clayey soil. The skerry mapped ½ mile ESE. of Littledale occurs about 50 feet above the summit of the Waterstones and is well exposed in the road-cutting 300 yards S. of the limits of the map.

Between the Greet and the Caunton Beck [*The Beck*].—Stone from skerry bands was formerly raised from several pits at Normanton, both in the village and near the Hall, and has been dug for road-metal about Hockerton. Between Normanton and Hockerton there are two main skerry horizons, about 40 and 80 feet, respectively, above the base of the Marl.

The lower skerry-belt is seen in the road-cutting SW. of Cork Hill, and clay from beneath the same belt was formerly dug at a brickyard ¼ mile SW. of Hockerton Moor Farm. The Hockerton-Kirklington road passes through the skerry-belt about ½ mile E. of Kirklington, and some thin bands of fibrous gypsum occur about 220 yards further west. A section, some 300 yards in length, is exposed in this skerry-belt near the head of the Hockerton branch of the Car Dike. Alongside the same stream about 150 yards S. of Nut Wood a well-shaft penetrated red marl and skerry with fibrous gypsum. The belt is again exposed at the NW. end of Roe Wood, in a 7-ft. section which shows two or three thin skerries in red and green marls; it also throws out the water of the 'Holy' well, E. of Holywell Farm, and is partly exposed in a hollow-way nearly ½ mile SE. of Whip Ridding Farm. Several old pits occur at a higher horizon in the middle of Redgate Wood, and springs issue at the same level from skerry, near the Kirklington-Eakring road, W. and SW. of Puddingpoke Wood. This higher skerry-belt forms a plateau in which stone is seen *in situ* at a few points, more especially in the valley S. of Dilliner Wood.

In Fox Holes Wood, and on the southern border of Eakring Brail Wood, several old pits are situated near the junction of Waterstones and Keuper Marl.

Two strong skerry-belts are exposed in the dumble W. of Mansey Common. These are apparently the equivalents of the skerries of Normanton and Eakring Brail Wood, but are here nearly 100 feet above the Waterstones.[1]

In a side-gutter of the dumble, about 10 feet deep, 500 yards E. of Coultas Farm, a 3-ft. bed of sandstone is seen, associated with red and grey marls and shales. In the dumble itself, ripple-marked flags form the water-channel 8 feet below the above-mentioned skerry. These two beds, or belts, form the prominent feature extending from this point to beyond Maplebeck. In Hagley's Dumble the lower belt is again well exposed, and a 3-ft. band in the higher belt was being quarried for road-metal in 1907 at Brecks Farm.

Maplebeck is largely built of skerry, which has been raised from numerous pits in this locality. Three skerry-belts are visible in the main street. Stone in the lowest belt (not inserted upon the 1-inch map) was raised from a pit SE. of the church, and the feature is traceable along the lower slopes of the main escarpment, to Hagley's Dumble, where the rock is again exposed. There are old pits in the higher skerry-belts about 200 yards S. of the church; it was probably from these that the stone for Newark Trent Bridge was raised. The skerry-belts are traceable by small features as far as Caunton, where they form the floor of the valley for some distance and throw out the springs which have deposited the tufa on the flat. A small section in the bank of The Beck, SW. of Bathleyford Bridge, shows marl with thin layers of skerry thrown into rather sharp anticlines and synclines, whose axes are at right angles to the trend of the valley. Higher beds form the plateau which slopes from Dilliner Wood to Coppice, Mather, and Duke's Woods. The upper Maplebeck skerries were formerly exposed in shallow pits in the lower part of Mather Wood, and they may now be seen forming a small syncline in the

[1] The difference may be due partly to discrepancy in the level at which the Waterstones boundary has been drawn. *See* p. 26.

dike at the NE. corner of the wood. Near Coppice Wood the highest dolomitic skerry-belts begin to come on, at first making no show, but soon developing features upon the slopes in Park Spring and Lady Woods.

Small tributaries of The Beck and the Car Dike have notched the plateau and developed spur-like features running nearly NE. and SW., and the Car Dike is responsible for the marked escarpment which trends south from Cheveral Wood. A well-dissected skerry flat, in which, however, stone is rarely exposed, dips towards Mickleborough Hill, where it forms the feature around the base of the hill and drops nearly to the 50-ft. contour in the lower part of Kelham Hills. Old stonepits occur near Newfield and Park Leys Farms.

Skerries equivalent to those at Normanton are exposed in the steep banks of the Car Dike, E. of Hockerwood; in some places they are considerably disturbed and covered by a heavy rainwash.

Copious springs issue from the skerry-belts in the hollow below Spring Wood, and the skerry itself is exposed by the roadside in the small beck descending from Averham Park. The section in the old Mickleborough Hill brickyard consists of 10 feet of marl with thin skerry, on 12 feet of red marl, on 4 feet of marl with thin skerry. The upper thin skerry—which is traceable at many points throughout the whole district and possesses characters intermediate between the dolomitic and siliceous types—forms a slight feature upon the hillside, but becomes more prominent upon the north.

There seems to be no evidence for the fault trending from Averham through Gorsey Hall as suggested in the previous memoir.[1]

Siliceous skerries form the flat top of Mickleborough Hill and give rise to the bold features between Averham Park, Cheveral and Muskham Woods, and Woodhouse Farm, and those between Cold Harbour and Bathley Hill Farm. Higher skerries occur as outliers in flat-topped hills near Worner Wood, Debdale Hill Farm, and Kelham Hills Farm. The dip-slopes have been sharply bevelled off by the old Trent at the Kelham Hills, and further north have been deeply notched by small brooks descending to the Trent flats, upon which low, but relatively large, alluvial cones have been deposited. Old pits for road-metal are numerous, situated in the siliceous skerry-belts at intervals along the escarpment, and they are perhaps still more common on the bevelled dip-slope between Debdale Hill and Bathley. Thin platy banded siliceous skerries are exposed in a deep gutter about ¼ mile NNE. of Kelham Hills Farm, and in deep gullies in Kelham Hills Wood.

The Kelham brickyard—recently closed—is situated about 1 mile NW. of Kelham, on the same horizon as the Mickleborough Hill brickyard, which it replaced. At the NW. end of the pit the following section is exposed:—

	Feet.
Marl and soil with fragments of siliceous skerry—up to ...	5
Red marls	5
Green marl with a little gypsum in shapeless masses... ...	1
Red marls with occasional bands of grey-green marl and a little soft skerry	10
Red marls with soft skerry	2
Red marls, &c.	10
	33

A considerable amount of white fibrous and saccharoidal massive gypsum occurs upon the south at about the middle of the section. A shallow bore-hole driven unsuccessfully in search of gypsum is situated near the roadside above the excavation.

Between The Beck and Goosemoor Dike.—Several old pits occur in the neighbourhood of Kersall, and skerry, along with shales with salt pseudomorphs and a little fibrous gypsum, is exposed, on the W. side of the road-cutting in the centre of the hamlet, in a shallow syncline, whose limbs dip

[1] 'Geology of the S.W. part of Lincolnshire,' *Mem. Geol. Surv.*, 1885, p. 17.

at 5° SSW. and 10° NNE. respectively. A higher skerry forms a plateau-like feature dipping gently in the direction of Caunton Lodge Farm. At Buckshaw Farm an old well-cistern is said to be excavated entirely in rock.

Several small exposures of skerry occur near Kneesall, and old stone pits are also scattered about the neighbourhood. A pond section, about 100 yards E. of the Smithy, shows an 8-inch bed of dolomitic sandstone; and ripple-marked skerry (ripples trending NNE. and SSW.) is exposed in a disused hollow road about the same distance NNW. of the Smithy. Gypsum 6-8 inches in thickness has also been found in the hill slope. An old brick-yard 770 yards NE. of the Smithy was worked in clay beneath the main skerry-belt. In the valley E. of this point strong springs issuing from these skerries expose a lower skerry belt and feed the stream occupying the hollow NNW. of Brockilow Farm, where, at a point named the ' Duck's Mouth,' a hydraulic ram is installed.

West of the scarp formed by the Kneesall and Laxton skerries, the above-mentioned lower skerry-belt forms a gently sloping plain, only a few feet above the top of the Waterstones, between Lound Farm and Wellow Park, and can be traced more or less continuously to the northern limits of the map.

The Laxton open Fields are upon the main skerry-belts. In the dissected spurs of Mill Field individual skerries shoot out in succession eastwards from beneath the overlying cover, and the skerry rubble becomes very abundant where the surface slopes eastwards faster than the dip of the beds. At the time of the survey a pit, 250 yards N. of the Windmill, showed a 4-ft. section with stone beds 9 inches and 6 inches thick respectively. The 9-inch bed, compact and suitable for building, had its under surface covered with fine salt-pseudomorphs, and rested upon a thin greenish shaly clay.

The skerry-belts are exposed in ditches and road-cuttings leading to the Fields at the western end of the village; no stone was seen thicker than the above-mentioned 9-inch band. Excavations in the valley south of the church are old fish-ponds.

The lowest skerry-belt (not shown on the map) is exposed in the stream section alongside the old fishponds below the Norman Fortress (' Camp '), where there are basins and falls due to calcareous tufa.

About 1,000 yards SSE. of Laxton Church, on South Field, a hollow road exposes two skerry-belts and at least four thin layers of fibrous gypsum. Some 300 yards E. of this exposure a shallow hollow represents the site of an old brickyard in the clays beneath the skerries. The old yards, ½ mile SW. of Egmanton Church, and in the S. flank of Winson Hill, are on the same stratigraphical horizon. In the hollows bounding the Laxton Fields there is a great accumulation of rainwash, amounting to some 20 feet on the N. side of the West Field. Enclosure evidently implies the saving of a great deal of soil.

About 200 yards N. of Egmanton Church a small fault, with a down-throw to the north-east, crosses the road. In 1888 W. H. Dalton recorded[1] a local dip of 7° SW. upon the downthrow side, where a 3-ft. skerry has been quarried under 4 feet of marl. During the present survey a local dip of 8° NNE. was observed upon the upthrow side, in a shallow pit W. of the road. Dalton also records a lower bed of stone, dug under 7 feet of marl, on the N. of the alluvium, 700 yards E. of the church. In 1909 a pit was opened for puddling-clay almost upon the same site (650 yards E. of the church), and showed 2 feet or more of skerry beneath 4 feet of marl and shale. Old brickyards occur E. of the road to Egmanton Wood and on the top of the skerry flat N. of Egmanton.

Opposite the sluice at Scarthing Moor Mill, more than 12 feet of marls and shales with ten green-and-grey bands (thin skerries) overlie 3 feet of red blocky marl. Ripple-marks are abundant in the skerries and shales, some crossing others at right angles, and in places the marl itself appeared to be ripple-marked. Excellent salt-pseudomorphs were obtained from these beds, which are a little higher than the main skerry-belts exposed near Stone Road End Farm.

[1] 'Geology of the Country around Lincoln,' *Mem. Geol. Surv.*, 1888, p. 9.

Belts of thinner dolomitic skerries, several of which have been indicated upon the map, occur above the main belts. Ossington Hall stands upon the highest dolomitic skerries of this district, which form a shelf with a stiff clay soil, extending about 2 miles S. of Ossington (Fig. 3, p. 29). Between Laxton and Scarthing Moor the tracing of the skerry-belts is rendered difficult by two faults trending N. and NNW. through Moorhouse and Egmanton Common. About fifty years ago stone was raised ½ mile ENE. of Laxton Church for the restoration of the churchyard wall.

In Kneesall brickyard the following section was exposed in 1908:—

	Ft.	In.
Soil with a few stones	1	6
Red marl with a green band	1	0
Olive-green clay and shale, skerry and race	1	0
Red clay, green on joint faces	4	0
Thin pink skerry	0	3
	7	9

The sites of brickyards no longer worked occur, at Caunton about ½ mile N. of the church; in the valley about 1 mile W. of Ossington; on the W. of the road about ¼ mile N. of Moorhouse; and S. of Norwell, where a thin skerry-belt occurs in 10 feet of red marl. Siliceous skerries occupy the ground E. of a line through Norwell, Norwell Lodge, and the ridge ½ mile W. of Crow Park Farm. There is no reason to admit the presence of Waterstones inliers SE. of Laxton, nor of a fault in an E. and W. direction S. of Norwell Lodge—suggested in the previous memoir—the somewhat abrupt southern terminations of the features being merely the natural denuded edges of the belts of siliceous skerries. It is highly probable that an outlier of these skerries exists beneath the Glacial gravels W. of Norwell Woodhouse.

Stone has from time to time been raised from the higher skerries, which form outliers of the parent mass beneath the floor of the Trent valley. The long dip-slope NW. of Crow Park Station and the slopes S. of Barrel Hill are covered by sandy loam due to the breaking down of the skerry and to the sandy nature of the associated marl. Four to five feet of red marl is exposed in an old brickyard at Castlehill, W. of Carlton Station; skerry occurs at the southern end of the section.

Fibrous gypsum, 5½ inches in thickness, was found at 33 feet in a well (with windmill pump) SE. of Barrel Hill. B. S.

North and north-east of Goosemoor Dike.—Owing to the indefinite character of the boundary, the line traced as the base of the Keuper Marl has no certainty. It has been fixed chiefly by reference to the well-marked feature made by the strong skerry-belts about 100 feet above the base. There are no clear exposures along the boundary between Bevercotes and Bilsthorpe, and sections of any kind in the lower part of the Keuper Marl of this district are almost wanting, being confined to a few shallow ditches and ponds. The same difficulty that had been felt by the previous surveyors was encountered in tracing the base through Bevercotes Park, as the Marl in this quarter appears to descend toward the north-west, which implies either a reversal of its usual dip or a fault with a northerly downthrow. The latter alternative was adopted on the old map; but, for reasons previously stated (p. 27), we consider that the former is the more satisfactory explanation, and best fits the evidence farther west and farther east. Unfortunately, the features are obscure in this ground, and the exposures of the strata are too small to exhibit clearly the direction of the slight dip; it may, however, be northward in the upper part of the stream in Bevercotes Park, though apparently southward in the lower part of the stream and in the beck west of Bevercotes. The supposed small outlier of Keuper Marl capping the hill immediately south of Bevercotes is shown as on the old map, because of the skerry-like aspect of the ledge forming the hill-top; but it is possible that the Waterstones boundary-line has been drawn at a lower horizon here than in the main escarpment. G. W. L.

The two main belts of dolomitic skerry are well developed in the Tuxford and Markham districts. In the railway-cutting at Tuxford, W. of the Great Central Station, the beds are seen to be rolling slightly, and give

rise to a shallow anticline followed on the east by a syncline in whose centre the section given below was exposed:—

	Ft.
Marls	4
Skerry	2
Marls	3 ±
Skerry and gypsum	6
Talus	15 ±
	30 ±

The gypsum occurs as fibrous veins up to 6 inches in thickness, and as crystalline plates, cementing marl and skerry into reddish masses which project from the sides of the cutting. Farther west a lower skerry, 3 feet in thickness, overlies a 4-ft. bluish stony layer with fibrous gypsum. In 1909, stone was raised, about 200 yards S. of the railway bridge over the Great North Road, from a shallow pit in which a skerry, 2 feet 6 inches thick, forms a small syncline whose limbs dip at 10° and 20° in southerly and northerly directions respectively (ripple-marks here trend within a few degrees of north and south). Stone has been quarried in many old pits in the neighbourhood of Tuxford, and cisterns and wells in the village prove that fibrous gypsum is fairly persistent in the skerry-belts. Skerry with gypsum is exposed in the road-cutting about 100 yards E. of the church.

There are many old stonepits between Tuxford and East Markham, W. of the G.N.Ry., which were chiefly worked before the enclosure of the open fields. East Markham is built to a great extent into the skerry-belts, and numerous walls and buildings are composed of the sandstone. Fibrous gypsum is also seen at several points, more particularly in the slope N. of the Smithy, and in the railway-cutting about ½ mile N. of the church, where gypsum also cements stone and marl into hard masses of rock.

The chief skerry-belts descend beneath the valley floor E. of Markham, where they throw out tufa-depositing springs (p. 61) similar to those of Scarthing Moor, Moorhouse, and Caunton.

Beneath the belts there is a thick stratum of stiff red marl, equivalent to that near Egmanton and Laxton, in which several brickyards have been worked—two N. of Tuxford, three in the neighbourhood of East Markham, and another ⅓ mile SE. of Sibthorpe Place. The Sunnybank brickyard at East Markham, opened in 1883, has a thin skerry in the higher part of the section.

Higher skerries, with a little fibrous gypsum, equivalent to those on the high ground E. of Laxton, are exposed in the long cutting between the Railway Works near Dukeries Junction and the G.N.Ry. Station. Near the road bridge S. of the latter station, the section shows two skerry belts, each about 6 feet thick, separated by 6 feet of red marl and underlain by similar marl. The upper belt is again exposed in the cutting S. of Dukeries Junction. A deep well[1] sunk at about the centre of the triangle formed by the lines NW. of Dukeries Junction Station passed through 198 feet of Keuper Marl and 215 feet of Waterstones, meeting the Bunter Pebble Beds at 413 feet. (*See* Appendix I., p. 78.)

The ground from Darlton Field to the S. of Ruddingwood Farm consists mostly of heavy clay land, like that E. of Egmanton Common Farm, with traces of a few thin dolomitic skerries. A higher skerry-belt forms a distinct but broken escarpment, with a loam-covered dip-slope, at Weston, Ruddings Farm, and Babbington Springs. Sandy loam also covers the dip-slope near Majors and America Farm.

Although in this less elevated northern area the more siliceous higher sandstones do not develop such marked features as they do further south, their peculiar lithological character is still maintained, a good example being furnished by the skerry-belt underlying Normanton-upon-Trent. Immediately beneath the belt there is a thick bed of red clay, and the marl on the dip-slope breaks down to a sandy loam similar to that near Crow

[1] Recorded by C. Fox-Strangways, 'Sections along the East Coast Railway between Lincoln and Chesterfield,' *Quart. Journ. Geol. Soc.*, vol. liv., 1898, p. 159.

Park, but relics of gravelly drift W. of Normanton and Ragnall Hall render the soil more sandy than it would otherwise be.

As in many other cases, the wells on the dip-slope all obtain water from the skerry-belt.

East of the Trent.—The Keuper Marls have been proved at several points beneath the alluvium and gravels of the Trent valley between Newark and Fledborough. Some particulars of the sections will be found in Chap. VIII., in which the valley-deposits are described.

The Marl forms a small cliff N. of Newark, traceable as far as the centre of Winthorpe. Slightly ESE. of Crankley Point the Midland Railway passes the bluff near the site of an old quarry, in which are some loose blocks of gypsum and skerry. The ground S. of the Rifle Range, E. of Newark G.N.Ry. Station, has been largely worked over for the deposits of massive gypsum mentioned above (p. 32). The quarries of Messrs. Cafferata[1] enter the limits of our map about 850 yards E. of the station; some old pits also occur beneath the Tea-green Marls S. of the Rifle Range, and expose over 30 feet of marls with deposits of gypsum at 7-8 feet and 15 feet from the base respectively. Some of the gypsum is stained red.

The Tea-green Marls form a greenish-blue to yellowish clay soil, easily traceable as far as the point where they disappear beneath the ancient River Gravels, and their continuation is indicated in a ditch section at the N. end of the small wood just N. of this point. They were formerly quarried in an old brickyard about ½ mile E. of Trow Bridge, this being their last exposure within the limits of the present map; they occur, however, beneath the Rhætic scarp of Windmill Hill, about ½ mile NNE. of North Collingham Church. North of Collingham, marl, partially masked by Blown Sand, protrudes through the gravels, and has been worked in two old brickyards, the southern of which exposes 2 feet of Blown Sand on 6 feet or more of red marl with very thin pieces of skerry.

The marl becomes once more prominent near South Clifton. Skerry, composed mostly of compacted well-worn (probably wind-blown) sand (p. 31) occurs on the high ground W. of the main road, and a similar thin skerry occurs in the escarpment at North Clifton, especially in the bank NW. of the cross roads E. of the village, and at the top of the bluff overlooking the Trent N. of the village. The dip-slope E. of the high road is covered by sandy loam, and old marl-pits have been opened at several points within the area covered by Blown Sand. In the railway-cutting W. of the station 3 feet of Blown Sand rests on about 27 feet of marl, the lower part of which is partly green.

In the steep bluff (Newton Cliff) overlooking the Trent a line of old quarries, extending nearly ½ mile in the cliff-face, indicates the site of workings for fibrous gypsum. Near the point where the river touches the bluff, the cliff rises some 40 feet above the alluvium and shows two very similar sections, the southern one, about 100 yards S. of the river-bend, being as follows:—

	Ft.	In.
Red marls, mottled green...	18	0
Gypsiferous belt	2	0
Mottled red marls	8	0
Dark grey-green shales and sandstones with salt pseudomorphs	1	6
Belt of gypsum in anastomosing veins, with red and green marls, shales and sandstones, on red marl ...	10 to 15	0

Better sections of the lower gypsiferous belt occur a little beyond the northern limits of the map.

The gypsum veins meet at various angles, and are rarely more than 3 inches in thickness. Above the gypsiferous horizon a dark olive-green layer, 1-2 feet thick, consists of brokenly laminated marl or shale which here and there hardens into a kind of skerry and weathers into small phacoidal fragments, somewhat like those of a fire-clay. B. S.

[1] *See* 'Geology of Newark and Nottingham,' *Mem. Geol. Surv.*, 1908, p. 53.

CHAPTER VI.

TRIAS (RHÆTIC)—(*continued*), AND LOWER LIAS.

Rhætic.

The Rhætic beds occupy a very small area in the south-eastern corner of the map. They form the northerly continuation of an outcrop continuous throughout the area covered by Sheet 126 to the south of Newark. When followed eastward beyond the limits of the present sheet, the outcrop, with overlying portions of the Lower Lias, forms islands which rise through the widely-spread sheets of river gravel east of the Trent valley.

In old classifications the Rhætic series included the Tea-green Marl which is now classed with the Keuper. In this district the Rhætic series begins with the '*Avicula contorta* Shales'; and between these shales and the Tea-green Marl there is a sharp line of division. Whether this division marks an actual unconformity is, however, doubtful, for traces of slight local erosion only have been noticed beneath the Rhætic shales, and there is no perceptible difference of dip between the two formations.

Near Newark the Rhætic beds are 33 feet in thickness. Their lower subdivision, the *Avicula contorta* Shales, averages about 15 feet in thickness and consists of black thinly-bedded fossiliferous shales with occasional sandy layers and sometimes a basal bone-bed of sandy or earthy texture, but this bone-bed is known to be absent at Newark. The upper subdivision is composed of beds of light bluish-grey marl with occasional fossils, interstratified with a few bands of compact argillaceous limestone, usually more or less nodular and discontinuous. It has been usual, in the Midlands, to regard this upper subdivision as the equivalent of the 'White Lias' of the south-west of England, but the correlation has been recently challenged[1] and it is perhaps advisable to apply the term 'Upper Rhætic' to these beds. The highest bed is frequently a hard compact homogeneous limestone, in texture not unlike the 'Sun-bed' of the west of England.

B. S.

DETAILS.

The full details of sections in the lower part of the Rhætics, exposed in an old gypsum quarry at Beacon Hill, about half a mile S. of our area, are given in the recent memoir on the sheet to the south.[2] These sections revealed over 20 feet of dark fossiliferous shales with thin intercalations of lighter sandy shale and sandstone, capped by grey marls forming the base of the Upper Rhætic.

Over the tract W. of Coddington Hall the outcrop of the Rhætic beds was traced chiefly by feature and by the character of the soil, but is much obscured by gravelly wash. The fragments of nodular Upper Rhætic limestone were also a useful guide. In a coppice, 400 yards NNE. of the Hall, a shallow pit, opened in Lias, reaches the uppermost Rhætic limestone.

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[1] L. Richardson, 'The Rhætic Section at Wigston, Leicestershire,' *Geol. Mag.*, dec. v., vol. vi., 1909, pp. 366–370.

[2] 'Geology of the Country between Newark and Nottingham,' *Mem. Geol. Surv.*, 1908, p. 56

No sections occur between Lingspot House (on 6-inch map) and the Foss Way, but the nodular limestones form a distinct shelf protruding from below the covering of Lias Limestone. This tract is studded with old pits, probably dug to extract Rhætic limestone.

Five furlongs ESE. of Trow Bridge, and just outside our map, the road to Brough (Sheet 114, N.S.) rises over a small hill—partly gravel-covered—where blue-black and yellow shales and marls were exposed in the wayside ditch. It was upon this evidence that the lower boundary of the Rhætics was drawn in this quarter.

Rhætic beds, capped by Lias, again form rising ground a short distance NE. of Collingham. Fish-remains were collected from black shales from a well situated 120 yards E. of the windmill, half a mile NE. of North Collingham Church. The débris consisted of black fossiliferous shales, grey marl, and pieces of white micaceous sandstone. B. S.

Lower Lias.

In the small area occupied by the Lower Lias in the south-east corner of the map, the outcrop of the formation is for the greater part obscured by Glacial gravels. Only the lowest of the Lower Lias subdivisions—The Hydraulic Limestone Series—is present, its greatest thickness—some 40 feet—being attained in the neighbourhood of Coddington[1]. The lowest beds, consisting of grey or blue-grey laminated shales, interbedded with fine-grained shelly limestone of blue-grey colour, follow conformably upon the Rhætic series. A few sections occur in old quarries on the dip-slope of Beacon Hill, south and south-west of Coddington Hall, close to or just beyond the margin of the map. Some of these exposures have been described in a recent memoir[2]. Fossils are occasionally plentiful, including remains of saurians, fish, crustaceans, plants and sometimes insects. The higher beds of limestone in these sections are of coarser grain and sometimes shelly; they contain *Psiloceras planorbis* in a crushed condition.

DETAILS.

One of the old stone-pits is situated a few yards S. of the vicarage, ¼ mile SE. of Coddington Hall. The well at the vicarage is 60 feet deep, and probably terminates in Rhætic beds. The dip-slope E. of Coddington Hall is covered by sandy loam in which fragments of the Lias limestone are common. Lower Lias on Rhætic limestone, dipping gently to ESE., is also exposed in a small section in a spinney about ¼ mile NE. of the Hall.

A pit, about five furlongs E. of Two Mile Ho., on the Foss Way, furnishes an obscure exposure varying from 15-24 feet in depth. A 6-inch bed of creamy blue limestone with an ammonite occurs at 6 feet from the surface. Other limestones exposed are of the ' fish-and-insect ' type.

Behind the plantation on the Rhætic scarp, NE. of Two Mile Ho., there are traces of several old pits which were probably dug in search of the fine-grained Rhætic limestone beneath the Lias. B. S.

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[1] *See* 'Geology of the Country between Newark and Nottingham,' *Mem. Geol. Surv.*, 1908, pp. 59, 60.

[2] *Ibid*, pp. 61, 62.

CHAPTER VII.

GLACIAL DEPOSITS.

General Account.

As mentioned in the first chapter (p. 5), the peculiarity of the Glacial deposits in the area of our map—a peculiarity extending also over the contiguous areas of Sheets 126 and 112, to the south and west—is the occurrence of small isolated patches of drift which imply the former glaciation of at least the greater part of the district, while the intervening tracts are practically devoid of drift. The principal patches occupy relatively high ground, and it is evident that there has been considerable denudation and sculpturing of the country since they were deposited, during which, no doubt, much drift has been cleared away. But it is characteristic of Glacial deposits that they are, from the first, very unequally distributed; and the present remnants probably indicate the localities where the drifts were heaped up most thickly, while the tracts now bare may have had a thinner covering or none at all.

The mass of Boulder Clay and Gravel which forms a short moraine-like ridge in the Bunter country at Blidworth (details, p. 47) appears from its composition to have been brought by ice flowing from NW.; while the thinner but wider patches on the Keuper upland near Kneesall (details, p. 50-1) contain detritus which has been derived from NE. It is probable from this and other evidence that the ice-sheets which covered, respectively, the western and eastern sides of the North of England both invaded the district during the course of the Glacial period, though perhaps not simultaneously. The detached patches of Glacial Gravel which occur principally near the north-western and south-eastern corners of the map may represent the close of the Glacial invasion, having apparently been deposited by flood-waters from the waning ice-sheets.

No other drift except these patches of gravel was found, within the limits of the map, on the Bunter outcrop north of Blidworth; but three miles beyond the northern margin of the Sheet an occurrence of Boulder Clay was recently noticed which deserves mention here, as it affords proof of the glaciation of the intervening nearly driftless country. The Boulder Clay in question has been well exposed during recent years in a brickyard alongside the Great Central Railway between Retford and Worksop, ¾ mile east of Checkerhouse Station. The excavation, now in abeyance, has been worked entirely in drift, consisting of sandy Boulder Clay overlying and intermingled with laminated loam and sand. The whole mass fills a slight hollow on the dip-slope of the Bunter Pebble Beds, at about 130 feet above O.D. The thickness of the Boulder Clay varies in different parts of the pit, up to a maximum of about 12 feet. Boulders, often well-striated, are numerous and range in size up to 3 or 4 feet in diameter. The majority are Magnesian Limestone, of which several varieties are represented; Carboniferous Limestone and

'DRUID STONE,' BLIDWORTH. A CEMENTED MASS OF GLACIAL GRAVEL.

sandstone, and Keuper sandstone blocks are present in less number; likewise a few dolerites or basalts; and a single block of quartz-porphyry was found, resembling the St. John's Quartz-felsite of the Lake District. This drift may have been brought in from the north-west, directly across the Carboniferous outcrop, but more probably it has travelled from the north, along the lower ground, as the assemblage of boulders suggests that it belongs to the same trail as the Boulder Clay at Balby near Doncaster.

Just as the above section demonstrates the glaciation of the Bunter country in the northern part of our map, so also is the glaciation of the practically driftless Keuper country north of Kneesall indicated by the drift that occurs on the Keuper upland to the northward, in the next map, at Grove near Retford and at Gringley-on-the-Hill, as described in the memoir on the Lincoln sheet[1].

In the memoir on the sheet to the south[2] it was noted that there appeared to be no Glacial drift actually within the present valley of the Trent. The same condition has been found in the continuation of the valley within the area now dealt with, the alluvium and river-gravel resting directly on Keuper Marl in all the deep sections that came under observation. The view previously expressed that the Trent has excavated this portion of its trench since the glaciation of the district is thus supported. The principal part of the excavation was probably done in Late-glacial times, soon after the area became free from its covering of ice. A rapid deepening of all the tributary valleys would necessarily follow the lowering of the main valley. This sharp erosion is no doubt largely, though not entirely, responsible for the present limitations of the Glacial deposits. G. W. L.

DETAILS.

South-western District, W. of the Keuper boundary and S. of the Chesterfield and Lincoln Railway.—The most important mass of drift in this area is that at Blidworth, which extends in an ESE. direction for more than a mile, and is about 60 feet thick. It consists of red Boulder Clay with sand and gravel. The best section is in the roadside near the church, where the clay is seen to contain fragments of Magnesian Limestone and many other erratics, including some of large size. The base of the drift has a level of about 490 feet above O.D. at its western end, and falls to the 400 ft. contour a little to the south of Blidworth Church. On the west and north the Boulder Clay appears to rest directly on Bunter, but to the south and east sand and gravel appear to emerge from beneath it. In arrangement as well as in composition the drift of Blidworth resembles that of Fishpond Hill, between Mansfield and Skegby (Sheet 112). Immediately south of the church there is a pit showing coarse sand, somewhat marly and with streaks of coal, but nearly free from stones. Outlying patches of the sand and gravel occur as far east as Rook Wood, and the so-called 'Druidical Remains,' about ½ mile WNW. of the church, seem to be merely a small outlier of gravel which has been cemented to a hard conglomerate and now stands out some 15 feet high like a rude monument (*see* Plate III.).

The numerous boulders around the buildings in Blidworth, or embedded in the drift, included many of Carboniferous rocks, along with others derived

[1] 'Geology of the Country around Lincoln,' Sh. 83, *Mem. Geol. Surv.*, 1888, p. 129.

[2] 'Geology of the Country between Newark and Nottingham,' Sh. 126, *Mem. Geol. Surv.*, 1908, p. 73.

from the Lake District. Among them the following were noticed (by Mr. B. Smith):—One of Shap granite, rounded, 1½ ft. in diameter, at the entrance to the New Inn yard; one of garnetiferous granophyre (like Blea Crag rock); several of andesite and a rhyolite, of Lake District types; several of dark crushed graywacke, ranging up to 2½ feet in length; Millstone Grits, up to 3 feet diameter; crinoidal Carboniferous Limestones 1 to 2 feet diameter; many of Magnesian Limestone; and a few dark basaltic blocks.

The other patches of drift, farther north, are much smaller, and are all composed of sand and gravel. Owing to the difficulty in distinguishing such material from disintegrated Bunter Pebble Beds it is probable that there may be more drift than has been shown on the map. On the western margin of the map, ½-mile SW. of Sookholme Church, a patch of gravelly loam with a few small igneous erratics caps a low ridge at a height of 270 feet above O.D. This ridge lies below the main escarpment of the Bunter, and shows that the escarpment had receded nearly to its present position before the gravel was deposited. Ratcher Hill, two miles E. of Mansfield, about 490 feet above O.D., has a small capping of gravel with some angular sandstone fragments. The road-cutting at Lockwell Hill, 1½ mile SW. of Bilsthorpe, exposes a few feet of drift at an elevation of 300 feet above O.D.; and on the south side of Rainworth Water, 1½ mile W. of Bilsthorpe, a small gravel-pit showed 4 feet of gravel composed of Bunter pebbles with some small erratics. At Bradmer Hill, 1½ mile SE. of Market Warsop, there is some sand and gravel containing masses of red marl, at an elevation of 350 feet above O.D.

Besides these definite patches of drift, isolated erratics of small size, for the most part of Carboniferous sandstones, are scattered sparingly over many parts of Sherwood Forest. R. L. S.

The railway cutting ½ mile W. of Ollerton Station affords a good example of the difficulty there is in recognising drift gravels on the Bunter country. The bottom of the section shows firm sandrock of the Bunter Pebble Beds, but this is capped by 5 or 6 feet of loose red pebbly sand, which is probably drift, as it includes a few angular blocks of Carboniferous sandstone, ranging up to 9 inches in diameter, though it is composed mainly of Bunter material. On similar evidence a small patch of gravel-drift has been mapped in the plantations E. of Rufford Lake, and other small patches on the west flank of the Maun Valley between Ollerton and Perlethorpe. All these patches are probably relics of Late-glacial flood-gravels, deposited before the streams had excavated their present channels. G. W. L.

A patch of stratified drift caps a low hill of Bunter Pebble Beds E. of Farnsfield Windmill where it is well exposed in a pit showing 4 feet of bedded sand and gravel resting unevenly upon the Bunter. Many of the stones in the gravelly patches and bands stand upon end; they include some partly subangular blocks of yellowish-white sandstone from 7 to 9 inches in diameter, along with subangular fragments of igneous rocks (andesite, dolerite and tuff), and many pieces of soft red and yellow sandstone or skerry. Some of the sandy layers contain numerous spherical bodies composed of well-bedded red micaceous sandstone of fine texture. These vary in size from that of a pin's head to a small marble, the majority being slightly larger than peas, while a few have been broken along the bedding planes. The spherules, though waterworn, are apparently of concretionary origin, but the cementing material seems to have been leached out. Similar spherules occur in the sandy drift of Bobber's Mill, Nottingham, and one or two were found in similar drift at Kersall Lodge. They appear in all these cases to be erratics which have been removed from their original matrix. They resemble the small concretions of rather coarser sandstone noticed *in situ* by Mr. Sherlock near the base of the Pebble Beds in the Maun Valley (p. 22), and there are similar concretions in the sands at the base of the Permian near Clowne. B. S.

North-western District, W. of the Keuper Boundary and N. of the Chesterfield and Lincoln Railway.—In the western part of this area the superficial sprinkling of drift pebbles and of small erratics of Carboniferous sandstone and igneous rocks is more pronounced than in the country

farther south, and is rarely absent. Besides this, there are, in the valleys of the Poulter and the Meden several mounds of sand and gravel with erratics, to which a Glacial or Late-glacial origin must be assigned.

The most striking of these mounds occurs in the bottom of the valley at Cuckney, where it rises as a conspicuous prominence known as Mill Hill. It is about 230 yards in length and 120 yards wide, its longer axis running NE. with the valley. At its north-east end the deposit is banked against Bunter sandrock. A pit for sand and gravel, about 30 feet in depth, shows the mound to consist of soft brownish sand, with irregular intercalations of gravel containing a few subangular blocks of Carboniferous sandstone together with some basaltic and andesitic erratics, some of which are of Lake District types. The prevalent dip of the deposit is easterly, but with false-bedding and some miniature faulting.

Another mass of gravelly drift occurs at Shireoaks Hill Farm, about ½ mile W. of Cuckney, capping a ridge and traceable for about 700 yards. It is not well exposed, but appears to consist mainly of coarse Bunter pebbles, the deposit resting on the Middle (Permian) Marl series. Its summit is approximately at the same level as the Cuckney mound, which is about 220 feet above O.D.

Lower down the Poulter valley, near the confluence of a smaller valley holding the Welbeck Lake, a group of five mounds, all approximately at the same level, occurs at Cat Hills Plantation and Pitiful Hill Plantation. The summits of these mounds closely correspond in height with those of Cuckney and Shireoaks Hill Farm. In the mound nearest the Lake, immediately E. of Cat Hills Plantation, a pit has been opened to a depth of 14 feet, showing sand and gravel similar to that of Cuckney, with numerous blocks of Carboniferous sandstone and a few of dolomite.

In the Meden Valley a conical hill at Elkesley Hill Plantation, about ½ mile W. of Gleadthorpe Grange, makes a prominent feature similar to that of Cuckney, but somewhat larger, being about 300 yards long and 200 yards across. It consists of gravel and sand, and its surface is strewn with numerous blocks of Carboniferous sandstone, some of which are a foot in diameter. Like the mounds of the Poulter just described, it occupies a position in the bend of the valley at the point of confluence of a tributary hollow, and at a corresponding height above O.D.

From the position of these mounds in relation to the valleys, it is evident that they were laid down subsequent to the inauguration of the present drainage system. Their distribution suggests that they are of fluvio-glacial origin, and mark the final stages in the glaciation of the area.

J. B. H.

Similar gravels cap the ridge E. of Blackcliffe Hill Plantation, near the junction of the Maun and Meden rivers, and are sparingly exposed in two small pits, which reveal their ' pocketty ' character; for the most part they appear to be only a foot or two thick, but thicken to 6 or 8 feet in hollows of the weathered Bunter sandrock. They protect the surface of the Bunter from disintegration, so that it rises higher beneath them than on neighbouring ground not thus protected. These gravels are interrupted on the E. by a small side-valley, but set in again at Warren Farm, and are traceable thence to Haughton, where they pass over the boundary of the Keuper Waterstones. On the low ridge of marly Waterstones between Haughton Mill and Decoy House, the soil is everywhere pebbly, and some of the ditches show a red pebbly loam resembling boulder-clay, but the material appears to be due to the mingling of gravel with weathered marl. The boundaries of the gravel-drift on all this ground are very indefinite and difficult to trace. On the opposite side of the Maun-Meden valley the higher ground NE. of Bothamsall has gravelly soil, and a few pockets of gravelly drift are revealed in the brickyard section N. of the village (p. 35).

These higher gravels, mapped as ' Glacial,' are similar in composition and arrangement to the slightly lower terraces at the Maun-Meden junction and E. of Haughton and Bothamsall, which are mapped as ' Older River Gravel ' (p. 53), and the gradient of both is in the direction of the present rivers. They undoubtedly mark successive and uninterrupted stages in the cutting down of the valley, and our classification is more or less

arbitrary. But we have indicated by the 'Glacial' colour the gravels which are on or above the rim of the present valley, and by 'Older River Gravel' colour those which lie definitely within it. G. W. L.

Eastern or Keuper District; from the Keuper boundary to the margin of the map.—The greater part of the Keuper outcrop is practically devoid of drift, but evidence of its former existence in some districts is afforded by the presence of far-travelled stones at the base of the alluvium in the minor valleys, while in a few other places patches of Glacial deposits still remain on the upland.

The character of the alluvial relics is exemplified in a section exposed in the dumble about ½ mile W. of Hockerton, which shows a stony layer under about 5 feet of recent alluvial loam resting upon an uneven and sometimes contorted surface of Keuper Marl. Along with many fragments of the local skerry the stones include subangular quartzites, probably from the Bunter; larger subangular blocks of yellow quartzitic sandstone, probably Carboniferous, some nearly 1 foot in diameter; smaller pebbles of basalt and schorl-rock; and small hæmatite nodules like those in the Lower Mottled Sandstones and Permian Breccia. Derivative stones of the same kind are common in the stream-bed.

Again, in the Wink W. of the Maplebeck road, stony clay up to 8 inches in thickness rests upon a disturbed surface of marl, and contains cherts, skerry fragments, yellow sandstones, white fossiliferous sandstones, coarse white grits, Bunter pebbles, and occasional igneous rocks amongst which were a rock like a limburgite with a ½-inch nut of olivine and an andesite with albite.

The absence of big boulders from these deposits is noticeable, but may imply that the drifts which have yielded the stones were similar to those near Kersall Lodge, in which the biggest erratics average little more than 1 foot in diameter.

Of the Glacial deposits still remaining on the Keuper, the largest patch covers the high ground between Norwell Woodhouse Common and Kneesall, and consists of Boulder Clay, resting in part upon sand and gravel. The section N. of Kersall Lodge, described[1] in 1888 by Mr. W. H. Dalton, in which 2 to 6 feet of Boulder Clay was seen to rest upon 12 feet of sand and gravel, is now overgrown; but we fortunately saw an excavation for telegraph posts on the main road, only 70 yards away, which revealed at least 6 feet of tough red clay with boulders, one of which, of Magnesian Limestone, lay at the bottom. The Boulder Clay covers the high ground as far as Kneesall brickyard, and is also preserved on the spur running in the direction of Hare Hill. It gives rise to a soil of stony loam, in which skerry fragments are subordinate to the far-travelled stones.

Sands and gravels were recently exposed in a new pit, 10 feet deep, situated a few yards N.W. of Kersall Lodge, where they rest upon an uneven floor of red and green Keuper shales. The sand occurs in streaks and patches, often cross-bedded and cut out by the gravels. The larger boulders, most of which are flattened, oval, or ellipsoidal, rarely exceed 9 inches in diameter; they include white, grey, green and yellowish-red soft micaceous sandstones and shales, along with many Bunter pebbles and a few yellow and white quartzitic sandstones, grits and fine conglomerates.

A collection of stones from a ploughed-down gravel pit on the fringe of the Boulder Clay W. of the road from Kersall Lodge to Kneesall Lodge, included yellowish-white fine-grained Carboniferous sandstones, sometimes with plant remains; Carboniferous limestones of different kinds; Carboniferous chert; calcareous sandstone with *Productus* and *Leptæna*, rather like the fossil-grit of NW. Yorkshire; a somewhat similar fossiliferous shale; sandstones of various colours from the Permian and Trias; Permian dolomitic limestones and sandstones, and fossiliferous limestone like that of Hylton, Derbyshire, or Knottingley, Yorkshire; fossiliferous Lower Lias limestone, and possibly Rhætic limestone; olivine-dolerite; and rhyolitic breccia. Mr. Dalton recorded also Chalk and Oolitic ragstone from the Boulder Clay. Gravel was formerly raised from this pit and from others E. of the road, as well as from Beacon Pits on Norwell Woodhouse Common.

[1] 'Geology of the Country around Lincoln.' *Mem. Geol. Surv.*, 1888, p. 128.

East of the road, 5 feet of stony and sandy clay is still exposed at one point, and an angular boulder of Millstone Grit, 1 ft. 4 ins. by 1 ft. 5 ins. by 1 ft. 3 ins., lay in the excavation. The old pits in Woodhouse Gorse, W. of the Smithy, were about 6 feet deep, and still show obscurely about 3 feet of a patchy deposit, in part brick-red sand with well-rounded grains, and in part clay, sometimes stuck full of stones.

Kneesall Windmill stands on a small patch of gravel in which there are several ploughed-down excavations; the relations of the Boulder Clay to the gravel are obscure in this quarter. Amongst other boulders noticed in this neighbourhood we may mention a subophitic dolerite, like Whin Sill, 1 ft. 7 ins. by 1 ft. 8 ins., at a stile about 600 yards W. of Kneesall Brick Works; a dolerite, 1 foot in diameter, nearer the brickyard; and in the yard, blocks of grit, sandstone, ferruginous sandstone and fossiliferous limestone; on Kneesall Green a felspathic and epidotic grit, with quartz veins, measuring 2 ft. by 1 ft. 5 ins. by 1 ft. 3 ins.; and on the parish boundary W. of Buckshaw Farm, a large block of dolomite and a porphyritic dyke-rock over 1 foot in diameter.

The small patches of pebbly sand in Kneesall Wood and near Kneesall Church are probably outliers of the larger mass.

Boulder Clay, not previously mapped, lies on the hill-top N. of Leyfields and continues on a narrow ridge to a tract of sand and gravel about ½ mile SE. of Ompton. The clay weathers to a stony loam, and among its boulders, none of which was over 1 foot in length, were noticed a spherulitic felsite; a vesicular lava, 9 inches by 7 ins. by 4 ins.; and a highly crushed mica-schist with quartz veins; besides the usual sandstones. Near Lound Farm there were also two or three fragments of Lower Lias limestone; and a boulder of andesitic breccia, 15 inches by 9 ins. by 6 ins., was found by Mr. Lamplugh by the roadside near the trigonometrical station west of Lound Wood.

North-east of Lound Farm some old pits about 4 feet deep, at the spots indicated on the map, exposed 3 feet of pale red sand with pebbles; this is at 280-290 feet above O.D., the same height as that at Kneesall Church.

Relics of drift occur N. of Norwell Woodhouse at the SW. end of High Wood, where 'PEBBLES' is engraved on the map. Similar traces exist S. and E. of Eakring, and at other places near Wellow, Ompton, &c., where 'BOULDERS' *or* 'PEBBLES' is marked on the map.

At Normanton, on the western border of the Trent valley, pebbles and small boulders are scattered plentifully upon the skerry dip-slope, and in a yard near the Hall there were subangular boulders of white and yellow sandstones up to 10 inches in size. Similar material occurs on a small rise about half-way between Darlton and Ragnall, where a pond section, about 250 yards NNW. of Farhill Farm, exposed 3 feet 6 inches of red and green clay with pebbles, skerry fragments, and patches of red sand. There may be some Boulder Clay present at these places like that of Kneesall, but the evidence was not sufficiently clear to warrant its introduction on the map.

The gravel which caps the Rhætic-Lias escarpment around Coddington Hall, E. of Newark, attains locally a thickness of at least 12 feet, as proved in wells. B. S.

In the small brickyard ½ mile W. of Wellow, the section shows patches and pockets of weathered stony clay, 1-2 feet thick, above the Keuper. Several boulders of Carboniferous sandstone are left on the floor of the pit, including one measuring 2½ ft. by 2 ft. by 1 ft., which is the largest erratic observed in the Keuper district. There are several smaller boulders of the same kind in the village street at Wellow, and one of basalt at the street-corner NE. of the church.

It may be mentioned here that at the S. end of Rufford Park a small sandpit in the Bunter, 150 yards E. of the bridge over Rainworth Water, between Deer Dale Wood and the Lodge, shows pockets of rough gravel at the top, among which was a 4-ft. slab of flaggy red sandstone like that of the Waterstones, and a small fragment of fossiliferous limestone probably from the Lias. The spot is only a few hundred yards from the present boundary of the Waterstones, so that the sandstone slab may be a remnant from the perished outcrop. The gravel is probably of Late-glacial age.

G. W. L.

CHAPTER VIII.

OLD RIVER GRAVELS AND LATER ALLUVIAL DEPOSITS.

General Account.

Reference has been made in the preceding chapter to the close relationship of some of the gravels mapped as Glacial to slightly later gravels mapped as River Gravel on account of their association with existing streams, and it has been mentioned that the distinction may in some cases be arbitrary. Thus the 'Glacial' gravel capping the Rhætic-Lias escarpment around Coddington Hall differs only in altitude from the 'Older River Gravel' of the Trent which sweeps round and across the lower part of the same escarpment; and the 'Glacial' gravel of Haughton is almost conterminous with the 'Older River Gravel' of the Maun between Haughton and Lound Hall.

In the same way, the difference between the 'Older River Gravel' and the slightly newer deposits mapped simply as 'River Gravel' is essentially a difference of level, though generally the pebbles of the newer gravels are smaller than those of the older gravels. There is however this further distinction between the older and newer gravels, that the latter usually lie on, and even below, the floors of the larger of the valleys, while the former rest on an eroded surface of higher level.

In short, the whole series of gravels in and around the present valleys mark the successive stages of their erosion since the close of the Glacial period. But it has been shown in previous memoirs[1] that even the newer gravels of the Trent valley are of considerable antiquity, and that the erosive capacity of the river has been greatly diminished since they were spread out, the present tendency of the enfeebled stream in this part of its course being to deposit its burden of fine-grained material rather than to excavate. Hence the recent alluvium on the floor of the valley has buried the gravels in many places so that only their higher portions emerge at the surface. Similar conditions are found also in the broad valley of the Maun and Meden below their junction, but above it these rivers are still eroding their channels, as are likewise most of the smaller streams of the district.

Older Gravel of the Trent.

Respecting the Older Gravels of the Trent around Newark, which extend eastward beyond the margin of the map, it is believed that they were deposited at a time when the river flowed eastward and passed through the gap in the Oolitic escarpment at Lincoln to an outfall into the North Sea in the direction of the

[1] 'Geology of the Country between Newark and Nottingham,' 1908, pp. 77–80; and 'Country around Nottingham,' 1910, pp. 58–61.

Wash. This view has been advocated by Mr. A. J. Jukes-Browne[1], but Mr. F. W. Harmer[2] holds that the gravels in question were deposited in a glacially-dammed lake which discharged for a time through the Lincoln gap. Into these hypotheses we need not enter, as the evidence lies wholly in the country beyond the limits of our recent work. In any case it is certain that the Trent had taken its present course for some time before its newer gravels were deposited. G. W. L.

DETAILS.

At the Devon Brewery, Barnby Gate, Newark, the Older Gravels are 19½ feet in thickness.

At Winthorpe the upper surface of the gravel rises about 30 feet above the alluvium. Clay is reported near the surface in the churchyard, while 300 yards SSE. of the church a pit exposed 6 feet of sand and gravel on disturbed marl. The stones of the gravel, as a rule, are rather small, averaging about 1 inch in diameter, but quartzite pebbles up to 6 inches and flints up to 2 inches are common. There are also fragments of Rhætic and Lower Lias limestones, yellow sandstone, vein-quartz and black chert.

In Langford village a well, sunk in gravel, measured 17 feet in depth. A gravel pit 300 yards NE. of Langford Hall exposed 6 feet of slightly current-bedded sand and gravel. Fine and coarse pebbles occur in different bands, and alternate with strips of sand up to 6 inches in thickness. East of the Old Hall the high-level terrace, here about 20 feet above the alluvium, leaves the road, and its dissected edge, turning eastward, passes beyond the limits of the map. A degraded remnant of the terrace probably forms the rising ground about Coney Green, where there is a good deal of loose sand, and another remnant may be represented by the patch of gravel SE. of Besthorpe Windmill.

On the opposite or western side of the Trent the only gravels recognised as belonging to this series are the patches which occur around Upton, SW. of Mickleborough Hill, which rise up to 50 feet above the Trent alluvium. They consist of sand and gravel with flints, and have been dug at several points. They are reported to be only a few feet (6-8) in thickness. B. S.

Older Gravel of the Maun-Meden valley.

A rude terrace occurs on the south side of this valley opposite the artificial partition of the streams (p. 58) at Conjure Alders. The outer bank of the terrace shows obscure sections of coarse gravel occasionally reaching 5-8 feet in thickness; a rounded boulder of Carboniferous sandstone, 8 inches in diameter, was noticed in this deposit. The slope between the terrace and the high-level Glacial gravel on the brow of the valley is veneered with gravelly downwash.

East of Haughton and Bothamsall there are ill-defined gravelly terraces on both sides of the valley, but the thickness of the gravel is rarely revealed. A road-cutting down the slope N. of Haughton Hall Farm shows 4-5 ft. of firm pebbly sand with clayey patches, very like Bunter but probably compacted River Gravel; there is an overgrown pit in the field W. of this road and others on the rise S. of the Farm, without sections. The prolongation of the gravel S. of the valley caps the low ridge on which Lound

[1] 'On the Relative Ages of certain River-Valleys in Lincolnshire,' *Quart. Journ. Geol. Soc.*, vol. xxxix., 1883, pp. 596–610; and in 'Geology of SW. Lincolnshire,' &c., *Mem. Geol. Surv.*, 1885, p. 90.

[2] 'On the Origin of certain Cañon-like Valleys,' &c., *Quart. Journ. Geol. Soc.*, vol. lxiii., 1907, pp. 486–9.

Hall stands; it contains many large pebbles principally from the Bunter; and the ridge itself is probably due to the lowering of the unprotected soft Waterstones on the south by the Bevercotes beck.

G. W. L.

Newer Gravel of the Trent.

These gravels follow a direction generally parallel to the present course of the Trent, but frequently spread widely over the solid rocks to the east, and cut terraces in the older gravels. East of the Trent, they rest upon the Keuper Marls north of Newark and form a well-marked terrace near Winthorpe, bordering the recent alluvium along the line of the Fleet. From Langford their eastern boundary extends beyond the limits mapped and reaches the rising Lias escarpment near Eagle Hall, Lincolnshire (Sheet 114). Farther north they extend from Collingham to South Clifton, beneath the Blown Sand, and again sweep in an easterly direction beyond the map, to within a few miles of Lincoln.

West of the Trent, the River Gravel forms an almost continuous belt from Averham, at the south margin of the map, to High Marnham, 10 miles farther N., where the valley becomes much narrower, and is practically occupied by recent alluvium. Beyond the constriction, however, the gravels set in again near Fledborough and continue to and beyond the northern boundary of the map.

In the more central parts of the valley, islands of gravel, rising 6-10 feet above the alluvium, testify to the former extension of the deposit over the flats. Borings and sections (pp. 55-7) at various points also prove its presence beneath the alluvium over almost the whole valley floor.

The distribution and composition of the gravel suggest that, while the main drainage of the period followed the line of the present valley, the river may sometimes have bifurcated near Clifton Hill and sent some of its waters in an easterly direction. In the south the pebbles average 1 inch in size, but gradually decrease to ¼ inch near Marnham and Fledborough, and at the same time the admixture of sand becomes more copious. Also in an easterly direction the gravels become finer and more sandy except where they have been derived locally from the coarse older gravels, and in this direction they are spread thinly over the solid rocks, forming a feather-edge to the main sheet in the Trent valley.

At the surface the gravels often show as slight elongated ridges running in the general direction of the river; east of Kelham, for example, these features trend east and west, parallel to the river-course. Many of the ridges appear to be original, but in some cases they have probably been accentuated by the action of small distributaries flowing parallel to the main river.

B. S.

DETAILS.

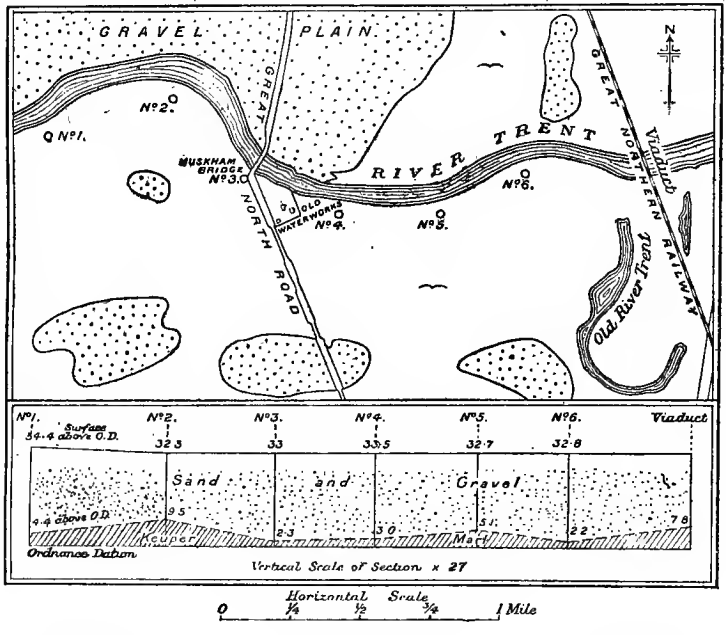
Fragments of siliceous skerry are common in the quartzite gravels W. of the Trent between Kelham and Cromwell; and flints and Rhætic and Lower Lias limestones also occur near Kelham. There are several old gravel pits near Averham, and 3 feet of sand and gravel is exposed in a pit nearly ½ mile SW. of Kelham Church.

In November, 1908, a good section of gravel was exposed in the river bank SE. of Kelham Bridge; the river at this point passing through a narrow channel in the gravels.[1] Other sections occur in old ballast pits on both sides of the high road (Great North Road) S. of Muskham Bridge.

The variable character of the valley-deposits near Newark is illustrated by a series of six borings through the alluvium S. of the Trent, near South Muskham, in connection with the Newark Waterworks, for the particulars of which we are indebted to F. Rayner, Esq., Assoc.M.I.C.E., of Nottingham. Three of these sections are given below, and the sites of the borings are indicated in Fig. 5. The beds down to the "rough gravel" in each section may be classed as Alluvium, and the remainder down to the Keuper Marl as River Gravel.

FIG. 5.—PLAN AND SECTION SHOWING BORINGS THROUGH TRENT VALLEY-DEPOSITS NEAR SOUTH MUSKHAM. (*B. Smith.*)

Heights given in the Section are in feet and inches.



No. 1. 34·4 ft. above O.D.	Ft.	In.
Top soil ...	4	6
Light clay ...	2	0
Boggy clay ...	2	6
Clay	1	0
Bog	2	0
Loamy soil ...	0	6
Rough gravel ...	3	6
Fine gravel ...	2	6
Rough gravel ...	5	0
	23	6
on Marl.		

No. 3. 33 ft. above O.D.	Ft.	In.
Top soil ...	3	6
Gravel	0	9
Light clay ...	1	9
Reddish clay ...	2	0
Greenish clay ...	2	0
Peat	0	6
Sand	0	6
Rough gravel ...	5	0
Brown sand ...	0	6
Gravel	6	0
	22	6
on Marl.		

No. 6. 32·8 ft. above O.D.	Ft.	In.
Top soil ...	2	0
Loamy sand ...	2	6
Rough gravel ...	10	6
Sand and gravel	10	0
Reddish sand ...	1	0
Greenish sand ...	0	6
	26	6
on Marl.		

[1] B. Smith, 'Some Recent Changes in the Course of the Trent,' *Geogr. Journ.*, vol. xxxv., May, 1910, p. 570.

A 25-ft. section through the alluvium and gravels (*see* p. 59), which was exposed when the railway viaduct over the Trent was constructed,[1] showed deposits of a similar character. At the Bottom Lock, near the Manure Works, Newark, gravel rests on Keuper Marl at 13-15 feet above O.D.

Gravel has been dug beneath the alluvium about ½ mile WNW. of Little Carlton, showing that the gravels here extend to the edge of the valley. Sand with gravel was exposed to a depth of 5 feet in the foundations of a new house about 150 yards N. of the inn at North Muskham, where there is an old ballast pit. In the bed of the river, near Muskham Ferry, the Keuper Marl occurs at 13 feet above O.D. In this district the low ridges of gravel have a northerly trend parallel to the course of the river. At the northern end of the Holme ridge there is a considerable tract of sand. Wells in the village are said to reach 18 feet in depth.

Between Kelham and The Oven, Cromwell, the river frequently exposes sections of sand and gravel to a depth of 6 feet or more. Two boreholes on the site of the new lock near The Oven, carried down to O.D. from the surface at 25-26 feet above O.D., were mainly in gravel and sand beneath a few feet of sandy and clayey alluvium, with alternations of coarser and finer material, as in the Muskham sections (p. 55); marl mixed with stones was reached in both borings at about O.D., and was penetrated for 5 feet further in the northerly boring[2]. Layers of dark sandy loam with plant-remains, bones and pottery were observed at two horizons in the gravel when the excavation of the lock was commenced.

In the banks of a water-filled ballast-hole alongside the railway W. of Cromwell 5-6 feet of gravel is still exposed. There are also ballast-holes W. of Carlton-on-Trent. At Cromwell the wells average 12 feet in depth. North of Cromwell the average size of the stones is about ½ inch, and they comprise—besides Bunter pebbles—flints, cherts, and fragments of siliceous skerry.

Gravel is thinly spread over the marls on either side of the Winthorpe road and the Foss Way N. of Newark. This gravel lies at a lower level and is finer than the Old River Gravel of Winthorpe, the average size of the stones being about ½ inch. Skerry fragments are fairly common.

Between Winthorpe and Langford the newer gravels form a distinct terrace rising about 10 feet above the alluvial flat, and lying some 10-15 feet below the older terrace. In Winthorpe, and W. of Langford Hall, the gravels throw out springs on the marl, and also at their junction with the alluvium. At the edge of the terrace, W. of the Smithy, Langford, 5 feet 6 inches of clean sand and gravel, with pipes of loam and pebbles, is exposed in a small pit—the average size of the stones being about ¾ inch, and skerry scarce.

The surface S. and SW. of Collingham is frequently sandy, and in South Collingham a belt of sand is said to extend through the village from the Rectory garden in the direction of the Low Street alluvial flat. In digging wells, clean sand is often reached at 5 feet. Ridges of gravel here run in a N.—S. direction, but they are elongated in an E.—W. direction in the isolated patch of gravel W. of North Collingham. The isolated patches near Cow-wath Pool and Mons Pool consist chiefly of sand, some of which is probably wind-blown.

At the W. end of Sutton-upon-Trent the gravels are thin and underlain by a skerry-gravel, but they attain their usual thickness in the centre of the village, and contain a considerable amount of interbedded sand. Gravel has been dug east of Grassthorpe. At Low Marnham 2 feet 6 inches of loamy soil rests on 1 foot 6 inches of fine gravel on running sand, and bubbling springs are found at 9 feet 6 inches.

The gravels E. and SE. of South Clifton are loamy, and contain much skerry, and are thinly spread over the marls which rise through them as islands. Mr. Cameron records[3] the following section near Clifton Harbour Inn, W. of Clifton Hill, the deposit rising to 15 feet above the modern alluvium.

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[1] F. Drake, 'Human Remains found with those of Extinct Animals in the Vale of Belvoir.' *The Geologist*, vol. iv., 1861, pp. 246, 349, &c.

[2] From information supplied by F. Rayner.

[3] 'Geology of the Country around Lincoln,' *Mem. Geol. Surv.*, 1888, p. 164.

	Ft.
Red soil with fragments of coarse grey sandstone	—
Alternation of fine and coarse gravel made up of rounded fragments of Triassic marl and sandstone	5
Laminated yellow clay	0½
Sand with carbonaceous streaks	2
Fine sand and gravel, as above	2+
	9½

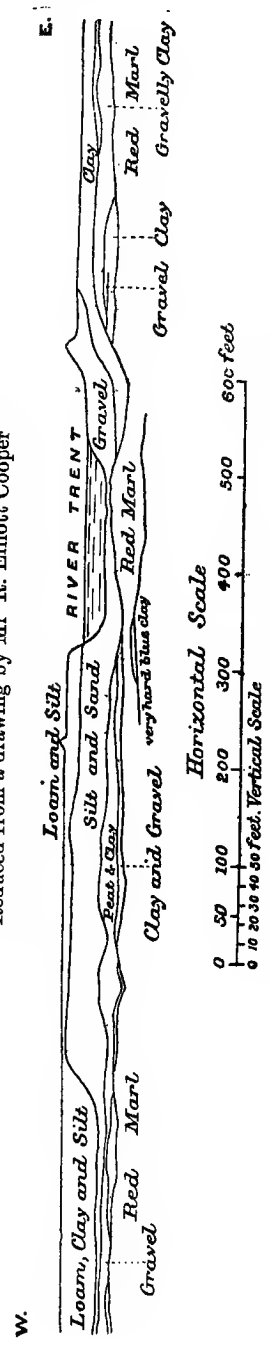

FIG. 6.—SECTION ACROSS PART OF THE TRENT ALLUVIUM NEAR FLEDBOROUGH.

Reduced from a drawing by Mr R. Elliott Cooper

Between Fledborough and Ragnall the gravels are covered by a very loamy soil. The piers of the railway viaduct at Fledborough go down 25–30 feet through deposits which consist chiefly of alluvium; some of the lowest beds, however, may belong to the gravel series. A section across the Trent valley at this point was published by the late C. Fox-Strangways[1] from a drawing by Mr. R. Elliott Cooper, the engineer of the railway; the main portion of the section is reproduced in Fig. 6. The floor of Keuper Marl below the river-deposits here averages about 10 feet below Ordnance Datum; as usual in the valley below Nottingham, it stretches from side to side with minor undulations, but without deep channelling.

B. S.

GRAVELS OF OTHER VALLEYS.

Some of the larger tributaries of the Trent, including the Greet, Maun, Meden and Poulter have deposited in their valleys flood-gravels which are probably of the same age as the Trent gravels just described, and similarly denote a period when their drainage was greater than it now is. These gravels are however so closely associated with the newer alluvium of the valleys, and so limited in area, that it was found impracticable to colour them separately from the Alluvium on the one-inch map, though in some cases they have been indicated by a modification of the symbol for Alluvium, and are entitled in the index of the map, 'Older Alluvium.'

Gravel of this character occupies a wide flat in the upper part of the basin of the Greet near Edingley and Kirklington. The

[1] 'Sections along the Railway between Lincoln and Chesterfield,' *Quart. Journ. Geol. Soc.*, vol. liv., 1898, p. 158, Pl. x.

stones are chiefly Bunter pebbles and there are no flints. Numerous springs are thrown out along the edge of this gravel, especially in Lower Hexgreave Park and near Springs Farm. A good section is exposed along the dike between Edingley and Kirklington Mills, showing about 5 feet of gravel with variegated loam or sand and patches of green loam from the underlying Waterstones.

The spur between the junction of the Maun and the Rainworth Water at Ollerton shows a succession of slight terraces thinly covered with pebbly and sandy wash; and remnants of similar terraces, usually too small to be shown on the one-inch map, are traceable here and there in the valleys of both streams above their junction. Below Ollerton some of the terraces are broader and have been indicated on the map; they rise 6-15 feet above the stream.

Where the Maun joins the Meden, east of Perlethorpe, and turns sharply eastward a curious condition has been brought about by artificial agency. The valley of the united streams has a broad flat floor, and to reclaim this land their waters have been divided at a weir at Conjure Alders, only 200 yards below the junction of the streams. One branch, retaining the name 'River Maun,' is carried along the southern edge of the flat, while the other branch, recognised as the 'River Meden,' is diverted to the north side of the valley, and the two streams then run parallel 300-600 yards apart, with the alluvial flat between them, for 4 miles further, until they are brought together again, nearly a mile beyond the northern margin of our map, close to their junction with the Poulter, the three streams here uniting to form the River Idle. Low ridges of sand and fine gravel occur here and there in the valley between the streams, and a coarser gravel forms a terrace below the rise of Older Gravel west of the Maun near Milton. G. W. L.

Alluvium of the Trent.

The principal tract of Alluvium in the map is that of the Trent valley. It consists chiefly of a broad central spread of loam wholly or partly covering the River Gravels. At the foot of the Keuper Marl slope, also, a belt of loam covers the outer edge of the gravel flat; and smaller strips varying from red clay or yellowish sandy loam to dark unctuous peaty clay have accumulated in the hollows and winding channels between the gravelly ridges. At the mouths of many small tributary valleys low fans merge insensibly into the alluvium: a series of these lies between Little Carlton and Bathley, and larger ones occur near Battle Bridge, Winthorpe Hall, Grassthorpe Mill and the moat south-west of Carlton-on-Trent.

In places where the gravels lie very close beneath the alluvial surface and on the flanks of the islands of gravel, which are often closely connected, the alluvium is sandy, since it is largely the product of flood-waters swilling over the sandy gravels.

Old channels of the Trent[1], partially silted up, are frequently met with, the most interesting being the Fleet stream, with its

[1] *See* B. Smith, 'Some Recent Changes in the Course of the Trent,' *Geogr. Journ.*, vol. xxxv., May, 1910, pp. 568–579.

expansions, between Winthorpe and Upper Girton Stakes, different parts of which have probably been occupied by the river at different times. Abandoned channels meander over the large 'Holmes' near Kelham, Muskham and Carlton, and others occur near the Cliftons and Fledborough. Where the parish boundaries leave the river, the latter has often found a new course during times of flood: it is thought to have separated Holme from Muskham at some date before 1576. The river appears during recent times to have slowly shifted from east to west within its valley, thus shortening its course somewhat between Averham and Marnham. At one time it worked along the gravel cliff on the eastern border of the flat at Winthorpe and Girton; now it occupies the middle of the valley, leaving a dissected gravel plain on its right, and tending to encroach upon the sheet of gravel on its left. This change may be due to the lowering of the channel in the narrow gap in the Keuper hills between High Marnham and South Clifton. B. S.

DETAILS.

The character of the alluvium at various points in the Trent valley may be judged by referring to the borings near Muskham, Cromwell, and Fledborough, given above (pp. 55-7). The alluvium of the tributary streams (*e.g.*, those near Battle Bridge and Winthorpe) frequently forms terraces some 2-3 feet above the general level of the Trent alluvium. Under Kelham Hills the alluvium is largely composed of sandy rain-wash, and the alluvial fans near Debdale Hill and Little Carlton are composed of similar material. East and NE. of Bathley the loam is spongy, dark and peaty, and frequently contains fresh-water shells and layers of gravel; it varies also in colour and consistency.

The gravels emerge very gently from the alluvium at the mouths of the Caunton Beck and the Goosemoor Dike, and these streams, as also those near Marnham and Fledborough, have comparatively narrow passages across the gravels in emerging on the Trent flats.

A digging for a sewage tank on the edge of the alluvium 100 yards N. of South Collingham Church showed 3 feet of surface soil, on 3 feet of clean sand, on 4 feet of gravel, on shale or bluish clay (? Keuper Marl). Beneath the soil W. of the church 18 inches of sandy peat rests on sand and gravel.

The old river-course represented by the Fleet still forms a Mere between Besthorpe and Girton, which once extended northward over the marsh opposite Girton. A channel of the river seems also once to have followed the inside course between Girton and Girton Grange. An alluvial wash lies in the hollow to the east of Clifton Hill, where the great flood of 1795 burst through the flood-bank.

In 1909 an oak trunk, 60 feet in length and 4-5 feet in diameter at the bole, and two smaller trees were dredged from the bed of the Trent a few hundred yards below the site of the New Lock and Roman Bridge at Cromwell. These probably descended the stream before the bridge was built, since trees of this size could not easily have passed between the piers.

Animal remains occur in some quantity in the alluvial deposits near the New Lock, Cromwell. Antlers of deer and a skull of *Bos* have been found by Mr. T. M. Blagg in a backwater at the Oven. Human remains[1] were discovered (p. 60), together with bones of ox, horse, and antlers of red deer, at a depth of 25 feet on the site of the Great Northern Railway viaduct near South Muskham. At Fledborough horns of red deer[2] were found at a depth of 25 feet in the excavation for the viaduct 400-500 yards

[1] *See* F. Drake and others, *The Geologist*, vol. iv., 1861, pp. 246, 349, 415, 495.
[2] C. Fox-Strangways, 'Sections along the Railway between Lincoln and Chesterfield,' *Quart. Journ. Geol. Soc.*, vol. liv., 1898, p. 158.

W. of the present river and near the margin of what appears to be an old course of the Trent. Animal remains[1] have also been found about 1½ miles further north.

Of the above-mentioned human remains found with pottery, &c., on the site of the G.N.Ry. viaduct, the skull was described by Huxley,[2] who concluded that there was no ground for supposing it to be older than "the historic or immediately prehistoric epoch." The position of the remains was probably due to lateral meandering of the river. Two black flint cores and a piece of rough pottery were found in the alluvium of The Beck near Maplebeck. These and the abundance of the remains of domestic animals between Maplebeck and Caunton suggest that a considerable settlement existed in this valley during Neolithic or later times.

Implements (celts, arrowheads, &c.) have been picked up at many points —*e.g.*, Averham, Newark, North Muskham, South Scarle,[3] Westfield (Collingham), North Collingham, Scarthingmoor, North Clifton[4], West of Tuxford, and Westwood Farm, Laxton. Bronze celts have been found at Newark, Combs (SW. of Farnsfield), Hexgreave, Holme, and Cromwell.

Worked flints occur in abundance on the east of the Trent valley near Collingham (Westfield), but are scarce on the west; a few, however, have been found on the Laxton Fields.

Roman remains (pottery, &c.) are of common occurrence to the east of the site of the Old Bridge near the New Lock, Cromwell:—Brough (*Crocolana*) on the Foss Way, a short distance beyond the E. margin of our area, being an important Roman station. Excavations have been here carried out by Mr. C. Smith-Woolley of South Collingham. Roman pottery occurs in quantity in the sands near the Mons Pool, and a portion of a *mortarium*, together with the base of a vase, were found during the survey in the Trent bank S. of the Roman Bridge. In the excavations for the New Lock a piece of Samian ware and a dressed block of Lower Lias limestone were found at 25 feet from the present river bank. B. S.

Trent Floods.

We have mentioned that changes of the river-bed have been common in the past, and it is evident that corrasion on the curves is still progressing in spite of the banks constructed to control the floods. The dredged channel now allows the waters to run off quickly, and at ordinary times drains the gravels which form a soakage reservoir mitigating the severity of floods. In spite of this, however, heavy rains following upon a thaw will send out the waters which are regulated during small floods by being confined to certain areas by transverse banks.

Several disastrous floods are on record. A great flood occurred in 1346, and in 1683 the Trent bridges at Nottingham and Newark were swept away; Muskham and Holme seem to have also suffered. Other large floods took place in 1730, 1774, 1790, and in 1770 when the Foss Dike Embankment near Torksey gave way and the waters reached Lincoln. The great flood of Candlemass (Feb.) 1795, was, like that of 1683, the result of a quick thaw, after seven weeks of frost. A barge unloaded coals at Collingham after navigating the lanes between the river and

[1] *See* J. F. Blake, Article on Geology in 'The Victoria County History of Notts,' 1906, p. 35.

[2] 'Note upon Human Remains from the Valley of the Trent,' &c., *The Geologist*, vol. v., 1862, pp. 201–4.

[3] Stone celt in possession of Mr. T. M. Blagg, Newport-Pagnell.

[4] Stone celt, 6½ ins. long, in possession of Mr. C. Smith-Woolley, S. Collingham.

the village. The outer bank (Wath bank) near Spalford, which is about 1 mile NE. of Girton Grange, burst at the SE. end of Clifton Hill, where signs of the flood are still discernible. The water reached Lincoln and submerged 20,000 acres W. of that city. With one exception it entered every house in Spalford; Girton village street was submerged 3 feet, and the waters rose to a height of 4 feet 6 inches on North Collingham Churchyard wall (31 feet 6 inches above O.D.). Large floods occurred in 1809, 1814, 1824, and 1852; during the last, it rose halfway up the wall of North Collingham churchyard, and Girton village street was inundated 2 feet deep. A sudden thaw produced a big flood in January, 1867; and in 1875 thousands of acres were deluged in the Trent valley[1]. Collingham, Girton, and the inn at High Marnham have floodmarks registering the height of the flood on this occasion. Low Marnham, protected by its encircling floodbank, was surrounded by water for three weeks. This flood was, at Nottingham, 5½ inches higher than that of 1852, 23½ inches higher than that of July 1875, and 28 inches higher than that of a later flood in January 1877. The flood of 1795 is estimated to have been 10 inches higher than that of 1875. Severe floods occurred in 1887, 1895 and 1901, and a recent flood reached its height at Nottingham on the 4th December, 1910. In the last case, incessant rains following upon a severe snowstorm, produced a flood against which the improvements in drainage and dredging of the river-bed were alike impotent. At Collingham the water rose to within less than a foot of the 1875 level, and it poured freely over the floodbank near Gainsborough.[2] B. S.

Alluvium of streams draining SE. and E. to the Trent.

The dip-streams on the Keuper Marl have, as a rule, narrow alluvial flats, composed chiefly of red loam, with a basal deposit of shelly and peaty loam sometimes containing animal and plant remains. Where, however, the main dolomitic skerries dip beneath the valley floors, the streams have spread themselves over the skerry, and the alluvial flats become wider. At the same time, springs issuing from the skerry-belts, just before they disappear, have deposited tufa. These wider portions of the valleys were occupied at times by shallow meres which were partially choked by reeds and mosses, and supported swarms of fresh-water mullusca. The tufaceous deposits, consisting of calcium carbonate with a very little magnesium carbonate, were chiefly formed in the central part of the flats, where the reeds strained off the coarse sediment. Since the drainage of the flats, the overlying and surrounding deposits of dark red loams, shelly loams and marls, and peaty loams have contracted or been denuded, so that the tufa now forms terraces rising above the other alluvial deposits. Sixty years ago the valley at Moorhouse

[1] A photograph of this flood at Nottingham is reproduced in 'Geology of the Nottingham District,' *Mem. Geol. Surv.*, 1910, Plate I. (front.).

[2] For detailed accounts of some of these floods, *see* J. S. Padley's 'Fens and Floods of Mid Lincolnshire,' Lincoln, 1881; Dr. Wake's 'History of Collingham,' 1867; C. Brown's 'History of Newark-on-Trent,' 1904; &c.

was a swamp: houses are said to have sunk at least 6 inches since proper drainage was instituted. The tufa preserves very clearly the impressions or casts of reeds (*Phragmites communis*), mosses (*Sphagnum*, &c.) and grasses; it also forms a coating upon stones, bones and drift-wood in the stream-bed, or cements sticks and leaves together to form small reefs over which the water cascades. These deposits, forming belts of very variable soil, are chiefly found near Caunton, Maplebeck, Moorhouse, Scarthingmoor and Kingshaugh near Darlton. Smaller deposits of the same kind occur near Laxton (the Camp), Egmanton, Weston, Grassthorpe and Kirklington. The larger areas of tufa are indicated on the map by blue stippling on the ground-colour of Alluvium. B. S.

DETAILS.

The Greet alluvium consists chiefly of red clay-loam with only a few gravelly and peaty layers as a rule, but is very sandy and pebbly near the Edingley-Kirklington gravels (p. 57). At the Silk Mill a boring for water pierced 18 feet 6 inches of alluvial deposits, the section being:—Red clay 3 feet, dark peaty clay 11 feet, gravel 4 feet 6 inches. Near Kirklington, springs have formed a small deposit of tufa, which is associated with dark peaty clay and fresh-water shells.

Alluvium of similar type occupies the valleys of the Car Dike and the Wink. About ½ mile W. of Hockerton the following section occurs in the side of a small alluvial terrace:—

	Ft.	In.
Reddish brown loam Thin layer of gravel Light brownish loam	2	0
Greenish loam	1	0
Light brown loam	1	6
Layer of stones, marl and sand	0	6
Red and grey Keuper Marl—disturbed	2	0
	7	0

The 6-inch stony layer is of interest; the stones are stuck in it at all angles, many being on end, and amongst them are boulders of yellow Carboniferous sandstones, basalts, and small pellets of red hæmatite—a collection bearing witness to the former presence of drift in the neighbourhood.

Similar local and Glacial rubble occurs in the valley of the Wink, on both sides of the road to Maplebeck, where it frequently rests upon disturbed marls. In this valley the loam contains remains of animals, and its base, which rests upon the stony deposit, is usually a dark-grey peaty loam with fresh-water shells and plant-remains (acorns, nuts, wood, leaves, &c.). The stony deposit is intermittent, and does not keep to one level.

The alluvium of the Egmanton Beck forms a low terrace where it joins that of Goosemoor Dike, just as the alluvium of the tributaries tends to form terraces above the Trent flats. Similar conditions occur at Moorhouse. Shelly loams occur beneath the red loam of Goosemoor Dike ½ mile E. of Grassthorpe. A skull of a horned sheep was found near this spot.

A well at Grassthorpe[1] on the modern alluvial flat showed:—

	Ft.
Rich soil and peat	10
Green moss	0⅓
Gravel, with bones of animals	2
Clay and water	2
	14⅓

[1] 'Geology of the Country around Lincoln,' *Mem. Geol. Surv.*, 1888, p. 173.

Collections of shells, plants, and animal remains have been made at various points in the valleys, the assemblage on the whole being similar to that obtained by Mr. W. B. Wright[1] from the alluvium of the Cocker Beck.

The following mammalian remains were collected by Mr. B. Smith and determined by Mr. H. A. Allen; the specimens are preserved in the Palæontological Department of the Survey of London:—

Bos; at Localities 2, 3 and 6 (*see below*).
Canis; at Locality 2.
Capra; ,, 6.
—— *or* Ovis; ,, 1.
Equus caballus *Linn*; at Localities 1 and 4.
Lepus; at Locality 2.
Ovis; at Localities 2 and 5.
Sus; at Locality 2.

1. About ½ mile E. of Maplebeck (numerous—lower jaw-bones, &c). 2. Tufa and shell loams, 120-150 yards S. of Caunton Church (numerous). 3. Hagley's Dumble, W. of Maplebeck. 4. The Wink, 120 yards W. of Winkburn Bridge (lower jaw). 5. Half a mile E. of Grassthorpe. 6. At or near Cromwell Lock.

Mr. Clement Reid identifies the following fresh-water and land shells and plants from the alluvium near Maplebeck and Kirklington in the collections made by Mr. B. Smith.

MAPLEBECK (Peaty Layer).

Mollusca.

Anodon sp.
Sphaerium (Cyclas) corneum *Linn.*
Bythinia leachi *Sheppard*
,, tentaculata *Linn.*
Helix (Fruticicola) hispida *Linn.*
,, (Tachea) nemoralis *Linn.*
,, (Patula) rotundata *Müll.*
Limnaea (Radix) auricularia *Linn.*
Limnaea (Limnophysa) palustris *Müll.*
,, (Radix) pereger *Müll.*
Physa fontinalis *Linn.*
Planorbis (Bathyomphalus) contortus *Linn.*
,, (Gyrorbis) vortex *Linn.*
Valvata piscinalis *Müll.*

Plantae.

Corylus avellana *Linn.*
Crataegus oxycantha *Linn.*
Quercus robur *Linn.*

KIRKLINGTON (Tufaceous Deposit).

Mollusca.

Carychium minimum *Müll.*
Helix sp.
Hyalinia (2-3 species)
Pupa (Pupilla) muscorum *Linn.*
Zua (Cochlicopa) lubrica *Müll.*

With regard to the plants, Mr. Reid states "there are no weeds of cultivation or cultivated plants."

In a similar deposit about 1 mile NW. of Maplebeck a collection of hazel nuts, hazel and oak wood, and willow leaves was made.

The following shells were collected from Scarthingmoor and named by Mr. C. T. Musson[2] in 1883. The section was "one foot of black soil [on tufa] full of shells, including":—

Bythinia tentaculata
Valvata piscinalis
Planorbis vortex
,, spirorbis
Limnaea peregra, v. ovata
Limnaea palustris
,, truncatula
Succinea elegans
Zonites fulvus
Helix hispida
,, pulchella
Pupa umbilicata
,, marginata
Vertigo pygmaea, &c.
Cochlicopa lubrica
Achatina acicula

[1] 'Geology of the Country between Newark and Nottingham,' *Mem. Geol. Surv.*, 1908, pp. 86, 87.

[2] *Journ. of Conchology*, vol. iv., 1883, pp. 162-163.

Mr. Gain, at an earlier date, found a single specimen of *Cyclostoma elegans*. This succession—peat on tufa—was also noticed by Mr. Gain at Egmanton and Grassthorpe; at the latter place he found the following species[1]:—

Sphaerium corneum	Limnaea peregar	Zonites fulvus
Anodonta anatina	„ palustris	Helix nemoralis
Bythinia tentaculata	„ truncatula	„ concinna
Planorbis spirorbis	Succinea elegans	„ hispida
„ complanatus	Zonites cellarius	„ pulchella
	„ nitidus	Cochlicopa lubrica

B. S.

ALLUVIUM OF STREAMS WEST OF THE KEUPER ESCARPMENT.

The alluvium of the streams crossing the Forest country is nearly always a sandy and pebbly wash derived from the Bunter. The Maun, Meden and Poulter have their sources in the Permian and Coal Measures west of the present map and receive hardly any addition in crossing the Bunter until they approach the Keuper boundary, where the Maun is augmented by small tributaries flowing from the Waterstones or from springs just below their base. The only streams actually rising from the Bunter are the Vicar Water and the Rainworth Water, which join the Maun. Nevertheless, the Bunter country is everywhere intersected by shallow valleys of erosion, evidently cut by running water. These small dry valleys lead down to the present river-valleys; their floors are still lined with water-borne sand and gravel; and they were evidently the channels of either temporary or permanent streams till a comparatively recent period. They indicate some change of conditions by which the surface 'run-off' has been stopped and the general water-level in the Bunter lowered.

The composition of the alluvium naturally varies with the character of the rocks over which the streams flow, but where a stream crosses from one formation to another it spreads the detritus from the rocks which it has left, over the next formation for some distance along its course. This is exemplified by the spread of Magnesian Limestone detritus over the Lower Mottled Sandstone in the alluvium of the Meden at Market Warsop (p. 65); by the sandy and gravelly alluvium of the Maun and Meden on the Keuper between Haughton and Milton; and by the red clayey loam of Keuper origin on the Bunter along the rivulet (Gallow Hole Dike) which joins the Rainworth Water in Rufford Park. Peaty alluvium is not common in the district, but patches were noted here and there on the swampy flats of the Rainworth Water and Maun, and in the soft ground along the stream (Bevercotes Beck) flowing N. past Kirton and Walesby. Above Ollerton the valley of the Maun for several miles has been converted into water-meadows by the construction of a high-level flood dike. G. W. L.

The Meden which enters the map south of Sookholme is margined S. of Hammer Water Bridge by an alluvial flat nearly ½ mile in breadth. This alluvium is exposed in the banks to a depth of about 6 feet, but its base is not reached by the stream. It consists of dolomitic gravel, sand and clay from the disintegration of the Magnesian Limestone, with larger blocks only slightly

[1] *Op. cit.*

rounded. The material was probably swept out of the Pleasley gorge in early Post-glacial times. Below Hammer Water Bridge the stream has excavated a narrow gorge in the Magnesian Limestone, but on leaving this formation its alluvium again expands to over ½ mile wide, here resting on the Lower Mottled Sandstone and extending as far as Warsop as a well-defined terrace rising up to 20 feet above the present stream. Recent excavations in the town of Warsop revealed sections of 13 feet in depth, without reaching the base, in dolomitic gravel, sand and clay. Beyond Warsop the terrace can still be detected as a feature for another mile as far as Assarts Farm. The more recent alluvium occurs at a lower level, bordering the stream as a narrow strip until it is lost beneath Thoresby Lake, which is of artificial construction.

The Poulter valley at Cuckney is straight and has evidently followed the line of a fault. Below Norton the Walling Brook joins the Poulter but is lost in the Great Lake of Welbeck Park, which has been formed by a dam thrown across the Poulter just below the confluence. Similar operations further down the stream have produced the lakes known as Carburton Forge Dam, and Carburton Dam. This chain of lakes has almost entirely submerged the alluvial flats for about three miles. J. B. H.

Blown Sand.

In the Trent valley, loose sand with well-rounded grains, occasionally shifted by the wind, covers the surface on the gravelly tracts N. of Trow Bridge and Westfield near South Collingham. It is doubtful whether this is entirely wind-drifted or whether the sand is partly intercalated in the gravels and exposed at the surface.

Undoubted Blown Sand, however, sets in N. of North Collingham, and extends, with slight breaks, to beyond North Clifton, swathing the rising banks of Marl or occurring as dunes upon the sheet of gravel; and similar Sand occurs upon the outliers of gravel which rise through the alluvial flat. Upon the banks of Marl the Sand almost invariably ascends on the western slope from the level of the alluvium to the summit, and then thins out on the eastern descent. On the steep slopes the Marl occasionally shows through the Sand, and in such places it has been dug for marling the surrounding light soil.

The Sand was evidently accumulated by S. and SW. winds blowing across bare tracts of sand and gravel on the river-plain. The date of accumulation was probably before the deposition of much of the present alluvium, for the latter often appears to overlap the edge of the Blown Sand.

The Sand consists of well-rounded grains of diverse size, and includes thin seams of small stones (flints and cherts), or isolated pebbles.

Collections of this Sand and other sands in the district were made, and separations of their heavy minerals effected. Mr. H. H. Thomas, who examined them microscopically, finds that these heavy residues are of considerable interest. The minerals present comprise garnet, augite, staurolite, hypersthene, tourmaline, rutile, zircon, anatase, monazite and iron ores. The staurolite and garnet have probably been derived from the Trias

of the neighbourhood, for both these minerals are abundant in heavy residues from the sands of the Bunter and Keuper.

Neither hypersthene nor augite, however, has ever been detected in the Trias, and the source of these minerals lay probably in the Glacial accumulations of the surrounding country. While Glacial drift which is supposed to have a northerly derivation (*e.g.*, at Farnsfield and Kersall Lodge) contains minerals indicative of Trias waste and lacks hypersthene and augite, other patches of Glacial sand, such as those associated with the Chalky Boulder Clay at Stathern and Belvoir (Sheet 142 N.S.), near the headwaters of the Devon, contain both these minerals in some quantity. Mr. Thomas has also noted the same minerals in the Glacial sands of the east coast at Lowestoft. It is probable that the Devon contributed largely to the Post-glacial river-gravel and sand from which the Blown Sand has been derived. B. S.

DETAILS.

On a heathy tract E. of the road between Besthorpe and Girton, the Blown Sand forms dunes arranged in lines, or *en échelon*, with their long direction nearly E. and W., and their steeper slopes facing north. A similar series, 10-15 feet high, occurs E. and SE. of Girton Grange.

At the old brickyard where the main road crosses a low hill of Marl, ½ mile N. of North Collingham, the sand is about 2 feet thick, but is considerably thicker on the hill-slope near the Fleet stream. The road leading from the village to Besthorpe Windmill is sunk below the level of the dunes. Sand was exposed to a depth of 8 feet in a pit on the south side of this road, while on the north it is seen in a new pit, 6-12 feet deep, in which the sand is slightly false-bedded (dipping slightly west of north), and includes a few seams of small stones.

Many of the grass-covered dunes have been ploughed down and exposed once more to the action of winds; as a result, the sands are banked up against the hedgerows, especially in the NE. corners of the fields, where there is often a 3-4 ft. drop to the level of the next plot. In Besthorpe Churchyard the sand is said to be from 12-14 feet in thickness. Near the Letter Box, ½ mile N. of Girton Grange, the 8-10 feet of sand exposed in shallow over-grown pits is said to rest on gravel on a hard marly band with stones. A cluster of dunes lies E. of the concave bend in the flood-bank. Good dunes are also developed NE. of South Clifton. At the top of the cutting W. of Clifton Station the Blown Sand is 4-5 feet in thickness. In this district considerable changes in the distribution of the sand have taken place since the previous survey.

On the west side of the Trent Valley the Blown Sand is confined to a few small patches near Carlton and Crow Park Stations, and these have probably been derived from the loamy outcrop of the sandy skerries and marl (p. 41) in this neighbourhood. This paucity of sand on the west side of the valley was also noticed further north by Mr. Ussher,[1] who attributed the sands which do occur in this position to local weathering of the Triassic sandstones. B. S.

In parts of the Bunter country where the old forest growth has been cleared and the land brought under cultivation, the sandy soil occasionally suffers from wind-drift during dry springs before it is covered by the growth of crops. This action is particularly noticeable in certain exposed belts where the Bunter sandstone is of finer texture than usual, as, for example, in a strip running from Boughton Brake to Warren Farm, near Haughton, and in the fields east of Rufford Forest. The drifted sand has not formed true dunes but has accumulated deeply under the lee of fences and in other sheltered places. G. W. L.

[1] 'Geology of the Country around Lincoln,' *Mem. Geol. Surv.*, 1888, p. 160.

QUARRY FOR GYPSUM IN KEUPER MARL AT HAWTON, NEAR NEWARK.

CHAPTER IX.

ECONOMIC GEOLOGY.

MINERAL PRODUCTS: BUILDING MATERIALS: WATER SUPPLY: AGRICULTURE: ETC.

COAL.

The proved extension of the Carboniferous rocks beneath the newer formations shown on the map, as described in Chapter II., must eventually lead to further development of coal-mining in the area. At present it contains only two collieries, both being near the western margin of the map; they are the Warsop Main Colliery at Warsop Vale, and the Mansfield Colliery near Crown Farm, Mansfield (for particulars see pp. 8, 74, 78). Preparations have been made for sinking a new colliery near Rainworth, at the southern end of Rufford Forest.

GYPSUM.

Fibrous gypsum was formerly obtained in considerable quantity from the river-bluff N. of North Clifton, and the face of the cliff is cut up by the old workings. A boring was put down some years ago, in search of gypsum, with little success, at the brickyard ¾ mile NW. of Kelham. Massive gypsum has been quarried from the Keuper Marl about ½ mile E. of Newark G.N.Ry. Station. The extensive gypsum-workings of Messrs. Cafferata and Co., at Newark, just enter the area described in this memoir, but fall principally in the map to the south (Sheet 126). A view of one of these workings is shown in Plate IV. The gypsiferous beds are approximately 60 feet in thickness, and their upper limits approach within a few feet of the bottom of the Tea-green Marl. A detailed description of these workings and of the uses to which the gypsum is put, is given in the memoir on Sheet 126[1]. References to the occurrences of gypsum in the Keuper Marl at other localities will be found in Chapter V., pp. 32, 39-43. B. S.

BUILDING STONE.

The best building stone of the district is obtained from the Lower Magnesian Limestone, but only the flaggy upper beds of this formation enter the area of the map, and all the principal quarries are situated beyond its western margin. These upper beds have been quarried, however, in places between Hammer Water Bridge and Warsop Main Colliery, also at Cuckney Hay Wood, for rough building stone and road-metal.

The thicker beds of brown sandstone in the Keuper Waterstones furnish a soft inferior building stone which has been quarried locally on a small scale around Eakring, Kirton and

[1] 'Geology of the Country between Newark and Nottingham,' *Mem. Geol. Surv.*, 1908, pp. 91–93.

Bothamsall, but is now no longer sought. The sites of most of the old quarries are indicated by a symbol on the map.

In the Keuper Marl country the principal bands of flaggy sandstone (skerry) were formerly raised from shallow quarries for local buildings, and are still occasionally got for this purpose. The tougher layers, if selected with care and allowed to weather through one winter, are not unserviceable; but an indiscriminate use of the stone has proved inadvisable, since some of it becomes honeycombed, or falls to pieces when exposed. The dolomitic sandstones are those principally employed (p. 29), and have been mainly raised near Hockerton, Maplebeck, Laxton, Tuxford and East Markham, at sites marked on the map.

Nearly all the churches on the local outcrop of the Keuper were originally built for the greater part of the skerry; but exposed portions, such as buttresses, angles, window sills, traceries, &c. have in many cases, after decaying, been replaced by better imported stone — chiefly from the Magnesian Limestone of Mansfield, or from the Oolite of Lincolnshire. Restorations and additions have also been carried out in other stone, but skerry has likewise been employed for this purpose quite recently. Amongst the erections built of skerry, we might mention as the more important or perfect the churches of Maplebeck, Kneesall, Moorhouse (poorly selected stone), Tuxford, Weston (where tufa from the Alluvium is also employed), Fledborough, and the old Bishop's Palace at Southwell. Newark Bridge is built of Maplebeck stone, and the Castle is partly faced with it. The walls of the Norman Keep [Camp] at Laxton are also of skerry.

Along the Trent valley the churches are often constructed of a mixture of skerry and limestone from the Lias area to the east, with the more exposed portions carried out in Oolite or Magnesian Limestone. The churches of North and South Collingham, Girton and Holme are largely composed of Lower Lias Limestone. Southwell Cathedral is built of Mansfield Woodhouse and Bolsover stone (Magnesian Limestone). B. S.

CLAY-WORKING: BRICKS, ETC.

The Permian Marls have been worked for bricks on a small scale in Welbeck Park and near Cuckney; there is also the site of an old brick pit at South Carr. A lenticle of marl in the Bunter Pebble Beds has been similarly utilized on the Thoresby estate, 6 furlongs SW. of Budby.

The belt of greenish-grey clay at the base of the Keuper Waterstones has been worked for bricks, tiles and rough pottery at several places along its outcrop, and is still dug at Bothamsall (p. 35), Wellow (p. 35), and Farnsfield (p. 34). At the last-mentioned place, red, yellow and glazed bricks are made on the spot, while the pottery clay, after being dug and washed, is worked up in the village.

The Keuper Marl has been raised for brick-making in many small brickyards most of which are now abandoned, owing to the competition of the larger and more modern workings in the districts N. and S. of the present area. The sites of most of the old yards, especially in the Tuxford district, are on the band

of good brick-clay beneath the main dolomitic skerry-belt (p. 32). A new yard, about 6 furlongs NW. of Kelham, has been closed down temporarily; and the only yard in work on the Keuper Marl at the time of the survey was that situated ½ mile E. of Kneesall (p. 41).

The Keuper Marl and the marly beds of the Waterstones were at one time extensively dug for marling purposes, particularly in the neighbourhood of tracts of light soil. Traces of the old marl pits were noticed in most parts of the Keuper area, but most numerously along the slope of the escarpment and near North and South Clifton.

MOULDING SAND.

The soft slightly loamy sand of the Lower Mottled Sandstone makes an excellent moulding sand and is extensively quarried for this purpose near Mansfield and at a few places farther north. The biggest pit is that of the Mansfield Sand Co., Ltd., which falls partly within the present map and partly in the adjacent map on the west (Sheet 112); a description of the section will be found in Chapter IV., p. 20, and is illustrated by Plate II., p. 20. The quarry averages 75 feet in height and is worked back in a series of terraces. The Lower Mottled Sandstone is confined to the lower 30 feet of the section, but the upper part, belonging to the Pebble Beds division, is utilized as a building sand and for other purposes. The moulding sand is sent by rail to various places, some being forwarded to a port for shipment abroad. Further details respecting the pits in the Mansfield district have been given on pp. 19-21. The Lower Mottled Sandstone has also been quarried in two pits at Warsop (p. 19) and in another at Cuckney Hay Wood (p. 15).

SAND AND GRAVEL.

The Bunter Pebble Beds are dug in all parts of their outcrop for the local supply of building sand, while the more pebbly bands are occasionally worked and screened for gravel. Most of the pits have been referred to in Chapter IV. (pp. 21-4).

Glacial sand and gravel are also quarried for similar purposes at Blidworth (p. 47), Cuckney (p. 49), Kersall and Kneesall (p. 50-1). The concentrated layer of pebbles at the surface of the Bunter Pebble Beds is frequently removed by shallow excavations for mending by-roads, &c., but is poor material for the purpose.

In the Trent valley, sand is obtained locally from sandy seams in the river-gravels and from the Blown Sand east of the Trent. Clean sharp sand dredged from the bed of the river is used for the sand-boxes of railway locomotives.

Dredging of gravel from the river-bed N. of Cromwell provides employment for a considerable number of men. At spring tides the lighters, each carrying about 100 tons, descend the river and carry their load to Immingham near Grimsby, where the gravel is being used in the construction of the new docks.

WATER SUPPLY.

The great water-bearing formation of the map is the Bunter, which is famous both for the quantity and for the quality of

its yield; and its area in this sheet is drawn upon not only for local supply but also for the supply of several large centres of population outside the district. Thus the city of Nottingham draws part of its water from wells 1 mile NW. of Boughton; Southwell and Newark are supplied from the Water Works near Farnsfield; Mansfield has its wells at Rainworth and Clipstone; and Sutton-in-Ashfield obtains its supply from a well near Rushley Farm. The site of all these wells are marked W. B. on the map.

The places within the map which have a separate public supply drawn from the Bunter are Warsop, Edwinstowe, and Blidworth; while Ollerton, Rufford, Boughton, Wellow, Kirton, Perlethorpe, Bilsthorpe and Budby obtain part of their requirements from the mains of the Nottingham Corporation from Boughton; and Farnsfield, Edingley, Upton, Averham, Kelham, Winthorpe, Langford and Collingham draw from the Newark mains. There are, besides, many private wells in the Bunter supplying the outlying farms and other residences. A few wells in the Keuper area have also been sunk deep enough to tap the Bunter, *e.g.*, at Tuxford and Newark, but the quantity of mineral matter in solution is usually found to be much larger in the water thus obtained than in the water from wells on the Bunter outcrop. This subject will be further discussed in a separate memoir on the water supply of Nottinghamshire now in course of preparation.

The Waterstones of the Keuper carry, in their sandy intercalations, a small quantity of water of fair quality, and the farms and villages on their outcrop that are not supplied from Bunter wells get their requirements from springs or wells in these beds.

In the Keuper Marl, the water resources are nearly always scanty and uncertain, being mainly confined to the skerry-belts, which in a few places throw out small springs (pp. 38-42). The water is also often undesirably hard, particularly when it has percolated along beds containing gypsum. The water supply of this district is mainly obtained from wells which are sunk to the water-bearing bands, but the yield is rarely abundant. The thicker sandstones of Tuxford, Laxton, &c. (pp. 29, 40-2) can usually be relied upon to yield sufficient for local requirements, but the quality is often indifferent.

In the valley of the Trent, most of the villages draw water from shallow wells in the river-gravel. The supply is generally copious, but is unsafe, owing to the risk of contamination from the surface. G. W. L.

AGRICULTURAL GEOLOGY.

The Magnesian Limestone of the western part of the district furnishes very variable soils. While typically yielding a brown loam, it frequently decomposes into a stiff clay almost approaching in tenacity that of the overlying Permian Marls. To some extent this may be accounted for by superficial relics of the marl on the dolomite, and in other cases it may be due to the weathering of thin bands of shaly composition that are included in the Magnesian Limestone.

The unmixed Permian Marl forms a very cold tenacious soil, but the thick intercalations of sand with the marl in the country north of Cuckney have produced a deep loamy soil which is the best agricultural land in the north-western district.

The Lower Mottled Sandstone yields a soil that, although light, is largely under cultivation, and in marked contrast to the area of the overlying Bunter Pebble Beds, which in the western district is only cultivated in patches. J. B. H.

The sandy and pebbly soil of the Pebble Beds is so friable and porous that it suffers severely during drought and is, besides, always a 'hungry' land, deficient in lime and needing constant manuring. Given liberal cultivation, however, and favourable seasons, it produces good crops, more particularly of barley, oats and turnips. As mentioned in an earlier chapter (p. 3) the Pebble Beds form the site of the old Sherwood Forest; and a large portion of the central area of the outcrop, extending from Welbeck Park through Thoresby to Rufford Forest, is still in the state of uncultivated park and forest land, far-famed and much visited for its sylvan scenery. Cultivation has encroached upon this forest land from both sides and also along the courses of the main streams. On the east the soil is rendered somewhat more loamy by the waste from the adjacent Keuper, while the valleys have been improved by the addition of stream-borne material; and on the west the enclosures have spread from the earlier cultivated slopes of the Lower Mottled Sandstone outcrop. In the unbroken land there are only patches here and there of the original forest, as in most parts the trees are of comparatively modern plantation. Nevertheless, the age and beauty of the older trees give distinctive charm to the noble parklands.

The prevalent soil of the Keuper Waterstones is a red clayey loam, slightly calcareous and generally stiff, but varying in texture according to the local changes in the proportion of sandstone to marl in the series. Most of the outcrop is under cultivation, except where the steepness of the escarpment has prevented agriculture, as at Eakring Brail, Wellow Park and Bevercotes Park, which are timbered. The belt of greenish-grey clay at the base of the formation (p. 26) weathers to a stiff yellowish or reddish soil, and has a breadth of outcrop disproportionate to its thickness, owing to the low relief of the ground where it occurs; this belt is indicated by the repetition of the word 'CLAY' engraved on the map. There is frequently a thick downwash of reddish-brown loam on the gentle slopes and in the hollows along the foot of the main Keuper escarpment, which gives rise to soils of great fertility. Hops, now no longer grown, were formerly cultivated rather extensively in the district, and most of the old hop-gardens had their sites on these deep-soiled tracts — *e.g.*, along the small stream (Boughton Dike) E. of Boughton; and in the hollow N. of Eakring—or on similar tracts of downwash on the lower slopes of the Keuper Marl—*e.g.*, near Tuxford and North Muskham. Orchards also thrive well on the Waterstones and are seen in all the villages along its outcrop.

The characteristic soil of the Keuper Marl is a stiff red calcareous clay, fertile but difficult to till and requiring subsoil

drainage. More loamy belts occur, however, where the sandy skerries are close beneath the surface, or where there is an admixture of coarse silt in the marl. Loamy soils are also noticeable near Normanton and Sutton-upon-Trent, Bathley and Little Carlton, where they may be partly due to the proximity of the sandy river-deposits of the Trent. The stiffest clays have a distribution indicating their derivation from particular bands in the Marl; they often occur on the slopes below the outcrop of skerry-belts, as, for example, beneath that of the main dolomitic skerries; but they sometimes expand widely on a dip-slope, as at various places on a north and south line from Darlton to Caunton. Over much of the country the Keuper soils are almost devoid of stones, but here and there they become charged with sandstone fragments derived from the skerries; and in the neighbourhood of patches of Glacial drift they are usually full of pebbles. The Keuper soils are generally favourable for wheat, and indeed for most field-crops when brought to good condition by tillage; they also grow excellent pasturage. In the neighbourhood of Laxton the open-field system of cultivation, now almost extinct in this country, still survives.

The area occupied by the Rhætic and Lower Lias in the south-eastern part of the map is small, and most of the ground is wholly or partly covered with Glacial Gravel yielding a gravelly or loamy soil, so that it is only on the slope of their escarpment that the darkish clay-land characteristic of the two formations is developed.

The soils of the Trent flats vary with the character of the underlying deposits. On the River Gravels they are rich gravelly loams, occasionally becoming sandy, that are fertile for most crops and easy to cultivate. Stiffer soils predominate on the later Alluvium, particularly where the side-streams have spread out their fine-grained loamy detritus derived from the Keuper Marl (p. 58). The villages of the flats are invariably placed on the gravelly tracts that rise slightly above the general level, but even in this position they are not immune from the higher floods. Before the deep dredging of the river and the construction of the elaborate system of banks, dikes and self-acting sluices, the lower tracts of Alluvium must have been very frequently under water. The Holmes and unfenced tracts near the river, that are still readily flooded, are kept permanently under pasture, while inclosed portions of similar land serve as hay-meadows. Where thick, the Blown Sand east of the Trent forms light poor soils, liable at all times to be damaged by wind-drifting; but where the Sand is thin the soil varies greatly from place to place, owing to the emergence of patches of Keuper Marl (p. 65).

The alluvial strips along the smaller streams are mainly kept under grass, but there is some tillage on the Older Alluvium of the Maun-Meden and Greet valleys and on the tufaceous deposits of the valleys draining eastward to the Trent.

G. W. L.

APPENDIX I.

SOME IMPORTANT BORINGS AND SINKINGS.

Bevercotes.

BORING ½ MILE SW. OF BEVERCOTES.

At bridge on by-road crossing Bevercotes Beck.

1-inch map (N.S.) 113. 6-inch map, Notts. 19 NE.

Communicated by the Wigan Coal and Iron Co., Ltd., per A. E. Webster, Esq.

Height above O.D. about 95 feet.

[Abridged from the original record.]

			Thickness. Ft.	Ins.	Depth. Ft.	Ins.
ALLUVIUM.		Clay	2	0		
		Peat	2	2		
		Grey sand	1	2		
		Sandy gravel	4	5	9	9
KEUPER WATERSTONES (base of).		Red loamy sand	1	6		
		Rotten red sandy marl	7	8		
		Blue loamy sand with mica	1	6		
		Red and blue sandy marl	15	1		
		Red shaly sandstone with mica	2	0	37	6
BUNTER.	Pebbles Beds, 567 ft. 9 in.	Red and grey sandstone	11	0		
		Red and blue marl, jointy	7	6		
		Red and grey sandstone and sandy shale	28	10		
		Red and blue sandy marl	2	0		
		Coarse red and blue sandstone, soft	116	2		
		Red marl	0	4		
		Red sandstone with gravel stones	134	6		
		Red marl	0	6		
		Coarse red sandstone, with gravel stones	266	11	605	3
	Lower Mottled Sandstone, 114 ft. 1 in.	Red sandstone	54	11		
		Red and grey sandstone, with bands and balls of marl	59	2	719	4
PERMIAN.	Upper Marl.	Red and blue marl	3	2	722	6
	Upper Magnesian Limestone, 25 ft. 6 in.	Light grey limestone with joints of marl	4	6		
		Red and blue sandy marl	2	10		
		Limestone containing shale	18	2	748	0
	Middle Marls and Sands, 153 ft. 4 in.	Red and grey sandy marl, shale, and sandstone	53	8		
		Red marl with spar cavities	5	6		
		Grey sandstone	0	3		
		Red marl	34	7		
		Red and grey sandstone, sandy marl, and shale	59	4	901	4
	Lower Magnesian Limestone, 202 ft. 3 in.	Dark grey limestone with spar cavity; brown limestone with shaly partings and bands, etc.	120	0		
		Grey limestone, with shale joints and bands	82	3	1,103	7
	Marl Slates.	Blue shale	26	6	1,130	1
	Breccia.	Conglomerate	6	0	1,136	1

on COAL MEASURES

Mansfield.

No. 2 Shaft. Mansfield (Crown Farm) Colliery.[1]

1-inch map (N.S.) 113. 6-inch map, Notts. 23 SW.

Height above O.D. 385 feet.

Communicated by Mr. J. P. Houfton.

[Abridged from the original record.]

			Thickness. Ft.	Ins.	Depth. Ft.	Ins.
		Soil	0	10	0	10
Bunter.	Pebble Beds (part of).	Sand and pebbles	46	2		
		Mottled sandstone [pebbly][1]... ...	40	4		
		Red sandstone	84	10	172	2
	Lower Mottled Sandstone. 111 ft. 8 in.	Red marl	5	1		
		Red sandstone with marl partings ...	15	4		
		Red sandstone	10	1		
		Red marl	5	2		
		Light red sandstone, marl pockets ...	25	10		
		Red marl	0	6		
		Light red sandstone, marl pockets ...	49	8	283	10
Permian.	Middle Marls.	Red marl with sand partings... ...	14	2	298	0
	Lower Magnesian. Limestone 68 ft. 6 in.	Magnesian limestone	1	5		
		Marl [red]	0	4		
		Magnesian limestone	0	10		
		Stone marl [hard red marl]	0	10		
		Magnesian limestone	1	11		
		Marl [red]	0	11		
		Limestone and stone marl in layers ...	4	0		
		Brown limestone	2	6		
		Coarse mottled sandstone	1	0		
		Brown and grey limestone	41	11		
		Blue limestone...	12	10	366	6
	Marl Slates.	Blue shales	98	7	465	1
	Breccia.	Breccia	2	11	468	0
	Coal Measures.	Soft grey rock	27	4		
		Red and blue shales	6	2		
		Red and grey rock	2	6		
		Blue and brown shales	1	0		
		Red and grey sandstone	2	0		
		Black bind [*Coelacanthus, Lepidodendron*]	0	1		
		Clunch, bind and rock	34	7		
		Coal	0	3	541	11
		Clunch and bind	1	11		
		Coal	1	2	545	0
		Bind, clunch and rock	91	7		
		Coal	1	7	638	2
		Stone clunch	4	5		
		Bind	9	2		
		Black bind [*Anthracomya phillipsi*]	0	11		
		Bind and rock, mixed...	27	9		
		Black bind [*Anthracomya phillipsi*]	0	10		
		Coal	1	8	682	11
		Clunch	5	11		

[1] Specimens of the beds passed through in the sinking were examined by Dr. W. Gibson. The words in square brackets are additions by him to the record. In the Coal Measures, unless otherwise stated, rock = sandstone; clunch = fireclay, clay and marl; stone-clunch = sandy marl; bind = shale; stone-bind = sandy shale.

		Thickness. Ft.	Ins.	Depth. Ft.	Ins.
Coal Measures—*cont.*	Bind, clunch and rock	52	6		
	Coal	0	7	741	11
	Clunch	2	8		
	Bind and rock	18	3		
	Black bind [*Anthracomya phillipsi*]	0	7		
	Rock and bind	18	9		
	Coal	0	4½	782	6½
	Black clunch	0	10		
	Coal	0	2		
	Black clunch	0	1		
	Coal	0	1½		
	Clunch and bind	8	1		
	Coal	1	1	792	11
	Clunch	5	10		
	Stone bind	25	2		
	Coal	2	7	826	6
	Clunch	2	2		
	Bind and rock, mixed	26	5		
	Coal	1	9	856	10
	Clunch	2	7		
	Coal	0	4		
	Clunch	1	10		
	Bind, clunch and rock	33	3		
	Coal	1	0	895	10
	Clunch	3	5		
	Bind	9	5		
	Coal	1	4	910	0
	Clunch	5	6		
	Bind	16	6		
	Stone bind and rock	22	1		
	Blue shale	5	5		
	Blue bind ... ... } Marine bed *see* p. 7.	36	5		
	Blue cank [Argillaceous limestone] } Marine bed *see* p. 7.	1	7		
	Blue bind	2	4		
	Coal	0	7	1,000	5
	Clunch	5	3		
	Bind and rock	37	3		
	Coal	0	11	1,043	10
	Clunch	1	7		
	Bind and stone bind	11	8		
	Coal	0	6	1,057	7
	Clunch	1	2		
	Bind	23	6		
	Coal	0	4		
	Clunch	5	0		
	Stone bind and bind	10	10		
	Coal	0	6	1,098	11
	Clunch	4	5		
	Bind	8	1		
	Coal	0	9	1,112	2
	Clunch	6	11		
	Stone bind and rock	39	3		
	Black bind	1	6		
	Coal. Clowne Coal	2	8	1,162	6
	Clunch	3	9		
	Bind	7	6		
	Coal and bat	1	1	1,174	10
	Clunch	8	0		
	Bind	58	10		
	Coal	2	2	1,243	10
	Clunch	8	3		

		Thickness. Ft.	Ins.	Depth. Ft.	Ins.
Coal Measures—*cont.*	Bind	51	8		
	Coal	2	9	1,306	6
	Clunch and bind	17	2		
	Coal	0	7		
	Clunch	0	10		
	Coal	2	4	1,327	5
	Light clunch	3	11		
	Bind	53	8		
	Black bind [*Carbonicola acuta*] ...	14	4		
	Dark blue bind [*Anthracomya phillipsi*]	14	11		
	Black bind	0	2		
	Coal. High Hazles Coal ...	3	9	1,418	2
	Clunch	1	3		
	Bind	36	8		
	Coal	0	8	1,456	9
	Clunch and bind	18	10		
	Coal	0	5		
	Clunch and bind [*Carbonicola*] ...	49	6		
	Batty Coal	0	11		
	Clunch	0	5		
	Bind and rock, mixed	37	0		
	Coal	1	0	1,564	10
	Clunch	1	1		
	Bind	7	0		
	Coal	0	8	1,573	7
	Clunch	1	3		
	Bind	12	10		
	Stone bind	23	9		
	Bind	13	3½		
	Coal. Coombe Coal	1	2½	1,625	11
	Clunch	0	3½		
	Coal. Top Hard Coal	5	2	1,631	4½
	Stone clunch	4	1½		
	Grey rock	19	4		
	Bind and clunch [*Anthracomya modiolaris, Naiadites modiolaris*] ...	35	0		
	Coal. Dunsil Coal	2	2	1,692	0

Oxton.

Boring for Water 900 yds. S 35° E of Baulker Farm.

1-inch map (N.S.) 113. 6-inch map, Notts. 28 SE.
Made by the Nottingham Corporation in 1896.
Height above O.D. 298 feet.

Summarised from detailed account in 'Geology of the Country between Newark and Nottingham,' *Mem. Geol. Surv.*, 1908, Appendix I. p. 111.

			Thickness. Ft.	Ins.	Depth. Ft.	Ins.
		Soil	0	6		
		Sand and gravel	2	6	3	0
Bunter.	Pebble Beds and Lower Mottled Sandstone.	Red sand	4	6		
		Red and grey sandstone with pebbles	21	6		
		Light reddish sandstone with pebbles and—in the lower part—marl beds	369	0	398	0
		Red marl	18	6		
		Light reddish sandstone with large pebbles and mixed marls.	74	9	491	3
	Permian.	Mixed marls	6	11	498	2
		Magnesian limestone	2	0	500	2

Rainworth.

WELL AND BORING (No. 1) OF MANSFIELD WATERWORKS.

1-inch map (N.S.) 113. 6-inch map, Notts. 28 NE.

Height above O.D. about 335 feet.

Communicated by Messrs. G. and F. W. Hodson.

[Abridged from the original record.]

			Thickness. Ft.	Ins.	Depth. Ft.	Ins.
		Soil	1	0		
BUNTER.	Pebble Beds.	Sand, sandstone, and gravel	9	0		
		Sandstone and boulders	3	0		
		Sandstone, variegated sandstones, and gravel	19	0		
		Sandstone and variegated sandstones	20	5		
		Coarse sandstone with small pebbles	46	1		
		Sandstone with small pebbles	5	9		
		Softer sandstone with hard veins and pebbles	27	5		
		Soft sandstone (sometimes variegated), with marl plies	39	9		
		Soft coarse sandstone	9	4	180	9
	Lower Mottled Sandstone. 96 ft.	Fine sandstone	4	6		
		Sandy clay, sandstone, and marl	3	8		
		Variegated sandy marls and sandstone plies	8	3		
		Light coloured sandy marls	4	2		
		Sandstone with marl	13	9		
		Fine hard sandstone and marl	16	0		
		Fine hard sandstone and variegated marls	20	3		
		Soft sandstone, full of water	14	6		
		Soft sandstone with hard bands	10	11	276	9
PERMIAN.	Middle Marls?	Sandy marl	5	11		
		Fine sandstone (some dark)	7	2		
		Marls	2	1	291	11
	Magnesian Limestone (upper boundary uncertain).	Fine sandstone	1	0		
		Very coarse sandstone	0	5		
		Marl	0	3		
		Coarse sandstone	0	10		
		Fine sandstone	8	0		
		Magnesian limestone	1	4		
		Clay	2	5	306	2

Southwell.

BORING FOR WATER AT SILK MILL IN THE GREET VALLEY.

1-inch map (N.S.) 113. 6-inch map, Notts. 29 SE.

Height above O.D. 90 feet.

Communicated by Mr. F. Allcroft, Southwell.

[Abridged from the original record.]

		Thickness. Ft.	Ins.	Depth. Ft.	Ins.
ALLUVIUM.	Red clay	3	0		
	Dark peaty clay	11	0		
	Gravel (a little water)	4	6	18	6

		Thickness. Ft.	Ins.	Depth. Ft.	Ins.
Keuper Waterstones.	Red, blue, and grey marl, and sandy marl, with gypsum	72	6		
	Hard grey sandy marl, red marl and gypsum	63	6		
	Very soft sandy marl, running into hole	3	0	157	6
	Dark red and blue marl	9	6		
	Coarse dark red sandstone	2	6		
	Red and blue marl and red sandy marl...	6	0		
	Coarse grey running sand	3	4	178	10
	Red, sandy marl, with soft and hard sandstone plies	63	0	241	10
	Light blue clay	12	0	253	10
	Very hard clay (thin band)	—			
Bunter Pebble Beds.	Light grey marly sand	20	0		
	Coarse red sand	11	2		
	Coarse red sandstone with harder layers	36	0	321	0

Tuxford.

Well at the Great Central Railway Works.

1-inch map (N.S.) 113. 6-inch map, Notts. 20 NW.
Height above O.D. about 150 feet.

Abridged from plans lent by Mr. C. Bressey, and from the detailed account by C. Fox-Strangways in 'Sections along the East Coast Railway between Lincoln and Chesterfield.' *Quart. Journ. Geol. Soc.*, vol. liv., 1898, p. 159.

		Thickness. Ft.	Ins.	Depth. Ft.	Ins.
Keuper Marl.	Red and blue marl, rock, and gypsum	198	0	198	0
Keuper Waterstones, 215 ft.	Red sandy marl, sandstone, sandy rock, red and blue marl, and thin veins of gypsum	179	0	377	0
	Red and blue sandy marl	7	0	384	0
	Blue sandy marl	29	0	413	0
Bunter Pebble Beds.	Sandstone, sand, and pebbles	237	0	650	0

The ground has since been lowered 6 feet, making the depth of the boring from the present level 644 feet.

The water-level is 54 ft. from the *present* surface.

Warsop.

No. 1. Shaft. Warsop Main Colliery.

1-inch map (N.S.) 113. 6-inch map, Notts. 18 SW.
Height above O.D. about 245 feet.
Communicated by Mr. H. Humble.
[Abridged from the original record.]

			Thickness. Ft.	Ins.	Depth. Ft.	Ins.
Permian.		Magnesian limestone [Lower] ...	94	10	94	10
	Marl Slates?[1]	Blue bind[1]	1	11		
		Brown limestone	1	6		
		Blue bind	9	5		
		Blue bind and ironstone girdles ...	109	8	217	4
		Hard grey rock [Breccia?][1]	5	0	222	4

[1] Owing to the similarity of the Permian Marl Slates to Coal Measures shales, there is some uncertainty in the classification when, as in this case, it is based solely on the mining record. For explanation of miners' terms, &c., *see* footnote on p. 74.

		Thickness. Ft.	Ins.	Depth. Ft.	Ins.
	Red marl...	10	4		
	Roll of ironstone	3	0		
	Blue bind	16	0		
	Grey rock girder	0	6		
	Red marl...	2	6		
	Blue bind	48	7		
	Coal	1	0	304	3
	Clunch	5	0		
	Dark grey bind	4	0		
	Coal	0	6		
	Clunch	0	6		
	Bind and rock, mixed	59	1		
	Coal	1	0	374	4
	Bind and rock, mixed	28	3		
	Coal	0	8		
	Clunch	1	7		
	Bind and rock, mixed	37	9		
	Coal	0	5		
	Band	1	2		
	Coal	0	5		
	Rock and bind	28	2		
	Coal	0	9		
	Clunch	4	9		
	Bind	11	6½		
	Coal	1	10	491	7½
	Clunch	0	6		
	Black bat and clunch	1	9		
	Coal	0	6		
	Clunch	1	6		
	Bind	16	9		
Coal Measures	Coal	1	6	514	1½
	Clunch	3	0		
	Bind	12	6		
	Grey rock	105	8		
	Black bind	0	10		
	Clunch	2	6		
	Bind and rock, mixed	23	10		
	Coal	3	0	665	5½
	Blue bind	68	4		
	Coal	0	4		
	Bind and rock, mixed	104	1		
	Coal	0	7		
	Bind	48	1		
	Coal	1	3	888	1½
	Gannister	0	11		
	Coal	0	7		
	Clunch and metal	3	6		
	Rock bind and stone bind	81	2½		
	Branch	0	3		
	Coal. Clowne Coal	3	0	977	7
	Clunch and bind	29	10		
	Coal and bat	1	3		
	Clunch	5	0		
	Stone bind and bind	40	8½		
	Coal	4	6	1,058	10½
	Stone clunch	2	3		
	Rock and bind, mixed	30	6½		
	Coal	1	1	1,092	9
	Clunch	7	0		
	Stone bind and rock	25	7		
	Coal	1	1	1,126	5
	Clunch	3	6		

			Thickness. Ft.	Ins.	Depth. Ft.	Ins.
Coal Measures —*cont.*	Blue rock		38	7		
	Coal and bat		0	2		
	Dark clunch		2	2		
	Coal and bat		0	4		
	Light clunch		3	0		
	Bind		85	8		
	Stone bind and rock [? High Hazles Rock]		20	9		
	Soft blue stone bind		14	7		
	Black bind		1	9		
	Coal	? High Hazles Coal.	3	2		
	Clunch		0	4		
	Coal		0	8	1,301	1
	Clunch		6	0		
	Coal and clunch		1	1	1,308	2
	Stone clunch		5	6		
	Strong grey rock		15	9		
	Bind and rock, mixed		35	3		
	Coal		1	4	1,366	0
	Strong blue bind		18	11		
	Coal		0	11		
	Clunch		1	4		
	Very strong grey rock		7	2		
	Strong blue bind		17	10		
	Coal and bat		1	8		
	Bind and rock, mixed		34	11		
	Ironstone bed and fossils		1	0		
	Black clunch		2	6		
	Grey rock and grey bind in layers		16	4		
	Bind and rock, mixed		57	5		
	Cannel coal		0	9	1,526	9
	Clunchy bind		2	5		
	Stone bind		1	0		
	Rock and bind in thin layers		1	3		
	Rock and cank, very hard		11	6		
	Strong blue bind		30	2½		
	Soft grey bind and streaks of coal		2	3		
	Coal, soft		1	4	1,576	8½
	Smut		0	1		
	Coal, soft		0	3	1,577	0½
	Clods, fairly free from ironstone		1	7		
	Bright coal	Top Hard Coal.	1	7	1,580	2½
	Harotz		0	6½		
	Softs		0	1		
	Brights		0	10½		
	Main hards		1	11		
	Brights, two sooty partings		0	8		
	Branch		0	10½		
	Soft coal and hard bands		0	6½	1,585	8½
	Clunch		5	6		
	Strong blue bind and ironstone bands and balls		6	6		
	Coal		0	7		
	Clunch		2	8		
	Bind and rock, mixed		34	7		
	Coal		1	2	1,636	8½
	Clunch		3	7		
	Rock		1	0		
	Strong grey bind		4	5	1,645	8½

Warsop.

WELL AND BORING AT BRADMER HILL, 1¼ MILE SE. OF MARKET WARSOP.

1-inch map (N.S.) 113. 6-inch map, Notts. 23 NW.

Made by Messrs. Vallance and Westwick, Mansfield, 1903-4. From section published by Mr. S. H. Wilson, in the "Warsop and District Almanack" for 1904.

Height above O.D., 329 feet. Water level, O.D. 203 feet.

			Thickness. Ft.	Ins.	Depth. Ft.	Ins.
Bunter.	Pebble Beds.	Soft red sand	20	0		
		Soft grey sand	5	0		
		Soft red sand	10	0		
		Mixed sand and pebbles	5	0		
		Gravelly sand	15	0	55	0
	Lower Mottled Sandstone.	Red sand (medium)	36	0		
		Red sandstone (medium)	9	0		
		Hard red sandstone (These figures are estimated from the drawing.)	3	0		
		Red sandstone (medium)	5	0		
		Hard red sandstone	1	0		
		Red sandstone (medium)	15	0		
		Bright red sandstone	51	0		
		Bright red sandstone, very hard	10	0	185	0
Permian Marl?		Sandy loam (bottom of boring)	8	0	193	0
Magnesian Limestone.		Hard Limestone	—			

Sections in adjacent Areas.

Additional information respecting the geological structure of the district is afforded by the following deep borings, &c. which have been carried out in adjacent areas, and have been recorded in the previous publications here mentioned:—

Locality of Section.	Depth of Section.	Published in
	Ft. In.	
GEDLING COLLIERY ...	1,382 10	*Mem. Geol. Surv.*, 'Country between Newark and Nottingham' pp. 102–4.
NEWARK, Boring for Water	801 6	„ „ p. 105.
OXTON „ Coal	2,050 –	„ „ pp. 109–11.
THURGARTON „ „	2,237 6	„ „ pp. 112–16.
WOODBOROUGH „ Water	479 –	„ „ p. 117.
SOUTH SCARLE „ Coal	2,031 –	*Mem. Geol. Surv.*, 'Country around Lincoln' p. 194.

For additional sections of Coal Measures, reference should be made to *Sheet* 88, *Vertical Sections Geol. Surv.* (1909), entitled "Sections of Shafts, &c., in the Southern Part of the Derbyshire and Nottinghamshire Coalfield."

APPENDIX II.

List of the Principal Works on the Geology of the District.

1835. Sedgwick, A.—On the Geological Relations . . . of the Magnesian Limestones, and the lower portions of the New Red Sandstone Series in . . . Nottinghamshire . . . *Trans. Geol. Soc.*, ser. 2, vol. iii, pp. 37-124.

1858. Aveline, W. T. E., Hull, and T. R. Polwhele.—1-inch Geological Map, Old Series, Quarter-sheet 71 NE. [Revised 1879.] *Geol. Surv.*

Aveline, W. T., and T. R. Polwhele.—1-inch Geological Map, Old Series, Quarter-sheet, 82 SE. *Geol. Surv.*

1861. Aveline, W. T.—Horizontal Section (Sheet 61, No. 2) from 2½ miles east of Chesterfield . . . across the Magnesian Limestone, New Red Sandstone and Marl, to the Windmill, 3½ miles east of Ollerton [with accompanying 'Explanation' of Sections 1 and 2; 6 pp.] *Geol. Surv.*

Aveline, W. T.—The Geology of the Country around Nottingham [Quarter-sheet 71 NE., with portions of 71 SE. and SW., Old Series]. *Mem. Geol. Surv.* (2nd Edit. in 1880.)

Aveline, W. T.—The Geology of parts of Nottinghamshire and Derbyshire [Quarter-sheet 82 SE., Old Series]. *Mem. Geol. Surv.* (2nd Edit. in 1879.)

Drake, F.—Human Remains found with Bones of extinct Animals in the Vale of Belvoir [S. Muskham Bridge]. *The Geologist*, vol. iv, pp. 246 and 349; and correspondence, pp. 415 and 495.

1862. Blake, C. C.—On the Crania of the most Ancient Races of Men. *The Geologist*, vol. v, pp. 205, 215-216. [Reference to skull found at Muskham.]

Huxley, Prof. T. H.—Notes upon some Human Remains from the Valley of the Trent, &c. *The Geologist*, vol. v, pp. 201-204.

1867. Murchison, Sir R. I.—On the parts of England and Wales in which Coal may and may not be looked for beyond the known Coalfields. *Rep. Brit. Assoc.* for 1866, *Sections*, p. 62.

Wake, Dr. E. G.—The History of Collingham, Newark-upon-Trent, and its neighbourhood, including the northern half of the Hundred of Newark. [Floods and changes of Trent.]

1869. Hull, E.—The Triassic and Permian Rocks of the Midland Counties of England. *Mem. Geol. Surv.*

1875. Tylden-Wright, C.—The Geology of Sherwood Forest and the District. Chap. xvi of R. White's "*Worksop, 'The Dukery,' and Sherwood Forest.*" 8vo. Lond. and Worksop.

1879. Aveline, W. T.—The Geology of parts of Nottinghamshire and Derbyshire [Quarter-sheet 82 SE., Old Series]. *Mem. Geol. Surv.*, 2nd Edit.

Aveline, W. T., E. Hull, and T. R. Polwhele.—1-inch Geological Map, Old Series, Quarter-sheet 71 NE. *Geol. Surv.* Edition of 1858 revised, with additions by W. T. Aveline.

Brown, Cornelius.—The Annals of Newark-upon-Trent, &c. London.

1880. Aveline, W. T.—The Geology of the Country around Nottingham [Quarter-sheet 71 NE., with portions of 71 S.E. and S.W., Old Series]. *Mem. Geol. Surv.*, 2nd Edit.

1881. Padley, J. S.—Fens and Floods of Mid-Lincolnshire. (With plan, p. 174, &c.). Lincoln.

1882. HARRISON, W. JEROME.—Nottinghamshire, in the *Geology of the Counties of England and Wales*, pp. 205-211. Lond.

HARRISON, W. J.—On the Quartzite Pebbles contained in the Drift, and in the Triassic Strata of England; and on their Derivation from an Ancient Land Barrier in Central England. *Proc. Birm. Phil. Soc.*, vol. iii, pp. 157-194.

WILSON, E.—On the Rhætics of Nottinghamshire. *Quart. Journ. Geol. Soc.*, vol. xxxviii, pp. 451, 452; and *Rep. Britt. Assoc.* for 1881, pp. 637, 638. (Newark only.)

1883. JUKES-BROWNE, A. J.—On the Relative Ages of certain River-valleys in Lincolnshire. *Quart. Journ. Geol. Soc.*, vol. xxxix, pp. 606-610.

MUSSON, C. T.—Subfossil shell deposits in Nottinghamshire. *Journal of Conchology*, vol. iv, p. 162-163.

1885. JUKES-BROWNE, A. J., and W. H. DALTON.—The Geology of the South-west part of Lincolnshire, with parts of . . . Nottinghamshire [Sheet 70, Old Series]. *Mem. Geol. Surv.*

METCALFE, A. T.—A Sketch of the Geology of Nottinghamshire, in White's *Directory and Gazetteer of Notts.*, Sheffield.

1886. DEELEY, R. M.—On the Pleistocene Succession in the Trent Basin. *Quart. Journ. Geol. Soc.*, vol. xlii, p. 462 [Coddington] and p. 464 [Blidworth].

HOLLOWAY, W. H., W. H. PENNING, J. W. JUDD, W. H. DALTON, and others.—1-inch Geological Map, Old Series 70 [north-western part] (in two editions: 'Solid' and 'Drift'). *Geol. Surv.*

PENNING, W. H., W. H. DALTON, A. C. G. CAMERON, W. A. E. USSHER, and others.—1-inch Geological Map, Old Series 83 [south-western part] (in two editions: 'Solid' and 'Drift'). *Geol. Surv.*

1888. USSHER, W. A. E., A. J. JUKES-BROWNE, and A. STRAHAN.—The Geology of the Country around Lincoln [Sheet 83, Old Series]. *Mem. Geol. Surv.*

1893. DEELEY, R. M.—The Geology of Nottinghamshire [Drift deposits], in *A Contribution to the Geology and Natural History of Nottinghamshire*, edited by Prof. J. W. CARR, pp. 27-31. Nottghm.

SHIPMAN, J.—The Geology of Nottinghamshire [Permian and New Red Sandstone] in *A Contribution to the Geology and Natural History of Nottinghamshire*, edited by Prof. J. W. CARR, pp. 10-25. Nottghm.

1894. METCALFE, A. T.—A Sketch of the Geology of Nottinghamshire, in White's *Directory and Gazetteer of Notts.*, 2nd Edit., with Bibliography to 1893. Sheffield.

1898. FOX-STRANGWAYS, C.—Sections along the Lancashire, Derbyshire and East Coast Railway between Lincoln and Chesterfield. *Quart. Journ. Geol. Soc.*, vol. liv, pp. 157-168.

1900. BONNEY, Rev. T. G.—The Bunter Pebble-beds of the Midlands and the Source of their Materials. *Quart. Journ. Geol. Soc.*, vol. lvi, pp. 287-303. (With sketch map.)

1905. BRIGGS, A. CURRER.—On the Available Coal Resources of District D (Yorkshire, Derbyshire, and Nottinghamshire). *Final Report of the Royal Commission on Coal Supplies*, part v, pp. 1-4, with map.

KENDALL, P. F.—Sub-report on the Concealed Portion of the Coalfields of Yorkshire, Derbyshire, and Nottinghamshire. *Final Report of the Royal Commission on Coal Supplies*, part ix, appendix iii, pp. 18-36. Map and section, plates 2 and 8.

1906. BLAKE, J. F.—The Geology of Nottinghamshire, Chap. I. in "A History of the County of Nottinghamshire," vol. i. *Victoria History of the Counties of England*, pp. 1-36. London.

1907. BURTON, F. K.—The Shaping of Lindsey by the Trent. 8vo. London.

HANDFORD, Dr. H.—Nottinghamshire Water Supply, in the *Annual Report of the Medical Officer to the County Council of Nottinghamshire*, pp. 71-85, with map facing p. 87. [Also published separately.] Nottingham.

HARMER, F. W.—On the Origin of Certain Cañon-like Valleys associated with Lake-like Areas of Depression. *Quart. Journ. Geol. Soc.*, vol. lxiii, pp. 486-490, with map, plate xxxiii.

1908. GIBSON, W.—The Eastern Extension of the Nottinghamshire and Yorkshire Coalfields, in *Summary of Progress of the Geological Survey . . . for* 1907, Appendix III, pp. 137-140. *Mem. Geol. Surv.*

LAMPLUGH, G. W., W. GIBSON, R. L. SHERLOCK, and W. B. WRIGHT. —The Geology of the Country between Newark and Nottingham [Sheet 126, New Series]. *Mem. Geol. Surv.*

LEMPLUGH, G. W., R. L. SHERLOCK, and B. SMITH.—Midland District, in the *Summary of Progress of the Geological Survey . . for* 1907, pp. 16-25. *Mem. Geol. Surv.*

1909. LAMPLUGH, G. W., J. B. HILL, and B. SMITH.—Midland District, in *Summary of Progress of the Geological Survey . . . for* 1908, pp. 16-24. *Mem. Geol. Surv.*

GIBSON, W.—Vertical Sections, Sheet 88, Sections of Shafts, &c., in the Southern part of the Derbyshire and Nottinghamshire Coalfield. *Geol. Surv.*

1910. LAMPLUGH, G. W., and B. SMITH.—Midland District, in the *Summary of Progress of the Geological Survey . . . for* 1909, pp. 11-14. *Mem. Geol. Surv.*

SMITH, B.—Some Recent Changes in the Course of the Trent. *Geogr. Journ.*, vol. xxxv, pp. 568-579.

SMITH, B.—The Upper Keuper Sandstones of East Nottinghamshire. *Geol. Mag.* dec. v, vol. vii, pp. 302-311.

1911. SHERLOCK, R. L.—The Relationship of the Permian to the Trias in Nottinghamshire. *Quart. Journ. Geol. Soc.*, vol. lxvii, pp. 74-117 (with a Bibliography).

B. S.

PHOTOGRAPHS.

In addition to the photographs reproduced in the Memoir, there are others in the Survey Collection which illustrate this area, and of which Lantern Slides or Prints may be obtained.

Amongst these are views of:—

The 'Druid Stone,' Blidworth.
Sherwood Forest Scenery.
Waterstones at Kirton.
Keuper Escarpment near Boughton Station.
Glacial Sand and Gravel, Cuckney Dam.

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MIDLAND DISTRICT—*cont.*

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Staffordshire :—

3 SW, SE ; 6 NE, SW, SE ; 7 NW, NE, SW, SE. ; 11 NW, NE, SW, SE ; 12 NW, NE, SW, SE ; 13 NW, SW, SE ; 16 NE, SE ; 17 NW, NE, SW, SE ; 18 NW. NE, SW, SE ; 19 NW, NE, SW, SE ; 22 NE ; 23 NW, NE ; 24 NW, NE ; 41 SW (Derby. 57 SW) ; 47ª NW (Derby, 60 NW) ; 54 NW (Derby. 63 NW, Leic. 22 NW).

Six-inch maps which are included in the one-inch New Series maps named above, but which do not contain any part of the Leicestershire and South Derbyshire and North Staffordshire Coalfields, are not published, but MS copies have been deposited in the Geological Survey Office, where they can be consulted, or copied, if desired, at the cost of draughtsmanship.

MIDLAND DISTRICT—*cont.*

MEMOIRS.

In addition to the Memoirs (Sheet-explanations) mentioned under the head of one-inch maps, District Memoirs on the North Staffordshire Coalfield (price 6*s.*), and Leicestershire and South Derbyshire Coalfield (price 6*s.*) have been published.

VERTICAL SECTIONS (scale 1 inch = 100 feet).

Price, 1*s.* 8*d.* each.

Sheet 86, Sections of Shafts, &c. in the Pottery Coalfield, North Staffordshire; 1901.

Sheet 88, Sections of Shafts, &c. in the Southern part of the Derbyshire and Nottinghamshire Coalfield.

For publications relating to other parts of the United Kingdom, reference should be made to the Catalogue, price 6*d.*, obtainable at all Agents.